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**EXAMINING THE MARKET POTENTIAL FOR NATURAL-GAS-
POWERED TRUCKS: BARRIERS AND OPPORTUNITIES FOR
PROMOTING ENVIRONMENTAL SUSTAINABILITY AND
ECONOMIC PROSPERITY**

by

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Research Report SWUTC/14/600451-00078-1

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August 2014

EXECUTIVE SUMMARY

Over the past decade, public concerns have grown over America's energy use and production. Pushes towards more environmentally friendly and sustainable sources of energy have moved out of fringe politics and into mainstream political discourse. Advances in drilling technology and increased exploration of shale gas plays have made natural gas more available and accessible. The abundance of natural gas has led to its growing role in the U.S. electric production and has provided the United States with an opportunity to become a net exporter of energy in the near future. The availability of natural gas, coupled with uncertainty in the liquid petroleum market, has prompted stakeholders to search out additional uses for this low-cost energy source. The result has been a large-scale effort to encourage the use of natural gas-based fuel within the trucking industry. Commercial long-haul trucks and truck fleets are a prime target of these efforts. The number of natural gas fueling stations around the country is increasing, and there are growing investments in new technologies and government incentives to retrofit and upgrade the nation's trucking fleet, making the logistics of a large-scale switch from a liquid petroleum-based fuel to natural gas much less complicated.

Historically, natural gas has been used for residential and industrial needs. Globally, however, the natural gas vehicle (NGV) market has allowed natural gas to expand into the transportation sector. Recent technological advances in natural gas extraction have allowed the U.S. to view natural gas as a viable alternative to liquid petroleum. NGV numbers have almost doubled in the past decade with around 20% of city transport buses utilizing the fuel. The U.S. is home to around 120,000 NGVs, a small percentage of the worldwide total of around fifteen million (Natural Gas Vehicles for America, 2011).

The low price of natural gas has allowed NGVs fueled by Compress Natural Gas (CNG) and Liquefied Natural Gas (LNG) to make inroads into the transportation marketplace, and has allowed consumers to take advantage of the price differential. Additionally, NGV adoption provides many external benefits, including strengthening national security and reducing emissions of carbon dioxide and other harmful greenhouse gases. These negative externalities, which are not calculated into most savings and cost models, have the potential to be reduced by expanding natural gas in the transportation sector.

Natural gas has been touted as the fuel of the future. Globally, the demand for natural gas has tripled over the past thirty years and is forecasted to grow another fifty percent in the next twenty years. As populations increase and developing nations escalate their demand for fuel, the global market will become increasingly more competitive. This increased competition may lead the U.S. to become susceptible to market fluctuations leading to a less secure future.

That being said, the U.S. is at a crossroads. The opportunities to have an updated comprehensive energy policy, that embraces natural gas, will allow the U.S. to continue to compete globally. Fracking technologies and the ability to access natural gas offers the U.S. the ability to harness a domestically produced fuel to power our homes, industrial needs, and our vehicles. It not only burns cleaner, improving air quality, but has given the

U.S. the opportunity to strengthen our national security with the possibility of becoming increasingly energy self-sufficient. Decisions and consensus are needed to produce an energy policy that will alleviate environmental concerns while promoting a secure and stable future.

With increasing global fuel demand, the U.S. is in the process of diversifying its energy sources which provides the benefit of not being subject to the volatility of the international fossil fuels market. The increased production and adoption NGVs, coupled with expansion of existing infrastructure, have the ability to immediately nudge the U.S. further in that direction. NGVs have the capability to bridge the gap between traditional fuel vehicles and emerging technologies which can reduce our dependence on imported energy fuels. On the federal level, there are incentives and an increasing desire to develop a comprehensive energy policy. States, in particular, have incentivized the development and use of natural gas, and refueling stations to level the playing field against traditional fossil fuels vehicles.

As natural gas begins to make inroads as a viable transportation fuel, the nation will need a proactive policy to address upcoming challenges. The technology is available, and price disparities lend themselves to the adoption of NGVs, and the infrastructure is following close behind. To aid in the adoption and expansion of NGVs, we propose the following in order to propose a national energy policy.

Assess the lessons learned from energy-rich states and adopt them as appropriate. Texas, Pennsylvania, and North Dakota are experiencing huge expansions in natural gas drilling, and, in turn, are facing the environmental and community challenges associated with hydraulic fracturing, commonly known as “fracking.” Texas has enacted legislation specific to its large communities to improve air quality with the Texas Clean Transportation Triangle. Second, produce a non-partisan environmental study. Every state appears to be addressing fracking and environmental issues in their own way. While local control is encouraged, there has yet to be a report released that is comprehensive and provides consensus. Without comprehensive reports, states and localities are forced to make decisions regarding fracking that are often based on biased reports or are susceptible to industry or environmental group pressure. This impedes the development of comprehensive decisions, which leaves businesses struggling to operate, while spending a lot of resources in the public affairs realm. Third, the abundance of natural gas and NGVs deserve federal and state research and development that can produce reports and policy suggestions so the U.S. can capitalize on the natural gas revolution. Similarly, R&D efforts stand to make enormous inroads into an expanding NGV market, producing more fuel-efficient cheaper vehicles.

These recommendations are by no means all inclusive, but would point the industry, environment, and the U.S. public in the right direction. The U.S. is now grappling with the fact that energy independence could be a reality. We have gone from fearing an end of fossil fuels to producing an abundant, cheap, clean burning fuel. The U.S. transportation system should embrace and expand its use of NGVs. NGVs provide the U.S. with the ability to utilize the abundant natural gas, improve air quality, all while strengthening our national security.

DISCLAIMER

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INTRODUCTION

Over the past decade, public concerns have grown over America's energy use and production. Pushes towards more environmentally friendly and sustainable sources of energy have moved out of fringe politics and into mainstream political discourse. Advances in drilling technology and increased exploration of shale gas plays have made natural gas more available and accessible. The abundance of natural gas has led to its growing role in the U.S. electric production and has provided the U.S. with an opportunity to become a net exporter of energy in the near future.

The availability of natural gas, coupled with uncertainty in the liquid petroleum market, has prompted stakeholders to search out additional uses for this low-cost energy source. The result has been a large-scale effort to encourage the use of natural gas-based fuel within the trucking industry. Commercial long-haul trucks and truck fleets are a prime target of these efforts. The number of natural gas fueling stations around the country is increasing, and there are growing investments in new technologies and government incentives to retrofit and upgrade the nation's trucking fleet, making the logistics of a large-scale switch from a liquid petroleum-based fuel to natural gas much less complicated.

Through a detailed analysis of natural gas trucks, fueling infrastructure, and case studies, this report seeks to reach conclusions over the role natural gas vehicles (NGVs) should play in the future U.S. transportation system.

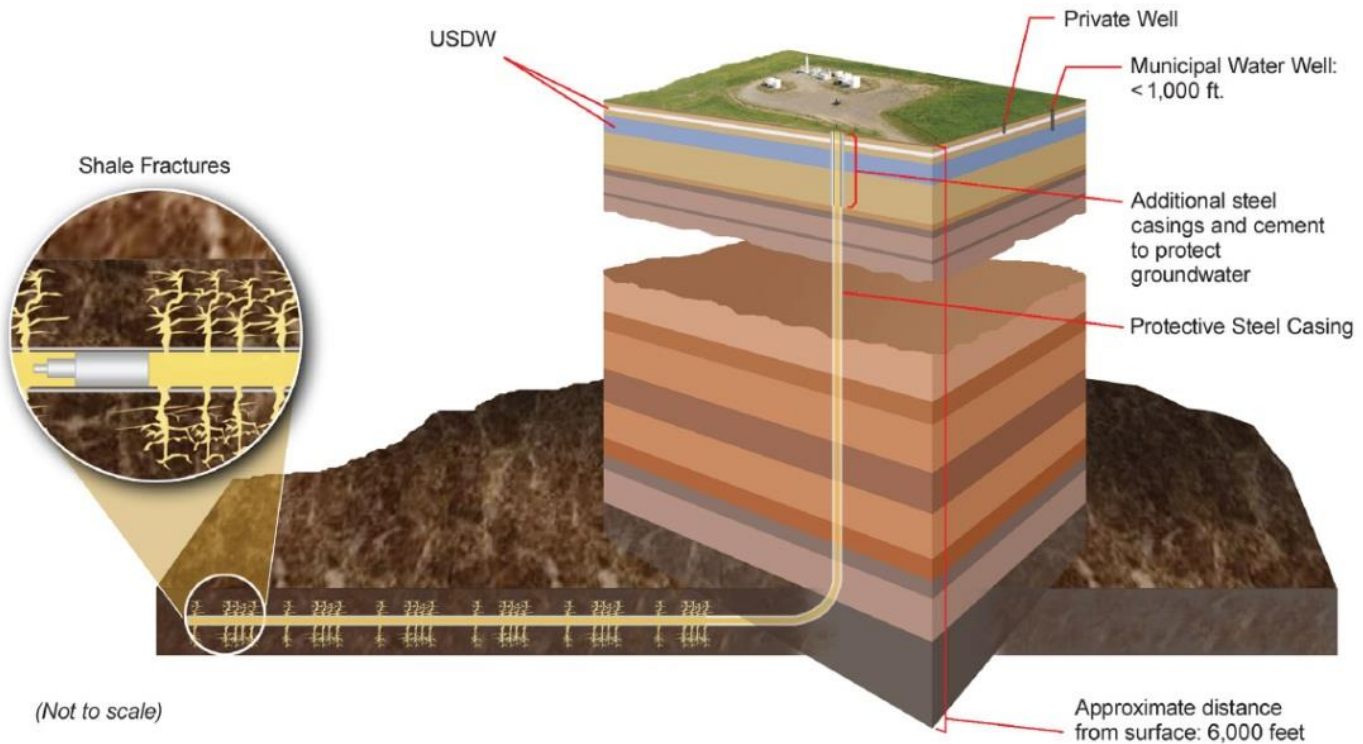
NATURAL GAS BASICS

Natural gas, sometimes referred to as the “eternal flame” in the ancient world, was first intentionally drilled in 1821 by William A. Hart in Fredonia, New York. Although natural gas was not “discovered” in 1821, it marked a shift towards commoditization of the naturally-occurring substance, eventually leading to its distribution by the Fredonia Gas Light Company to customers wanting to power lights on city streets. Natural gas became the preferred fuel for lighting until the large-scale advent of electricity and the electrification of cities in the late 1800s pushed the natural gas market in another direction. Robert Bunsen’s invention, the “Bunsen Burner,” opened a new market for natural gas: cooking and heating. While the Bunsen burner was invented in 1855, technological advances that followed World War II allowed for the creation of a pipeline infrastructure for widespread commercial and residential adoption (U.S. Department of Energy, 2013c). Until recently, natural gas has been mainly restricted to use as fuel for cooking and heating, but the shale or unconventional gas boom in the U.S. has led to further growth for the natural gas market, expanding into the transportation sector.

The current increase in production can be traced back to the advent of the hydraulic fracturing technique, commonly known as “fracking.” The drilling technique injects water, sand, and various chemicals at high pressure into shale formations, cracking the rock, and creating pathways for the trapped natural gas to flow through the well (Yergin, 2012). Mitchell Energy, run by George Mitchell who is credited with the modern fracking movement, did not invent the technique first used in the 1940s, but rather experimented with and invested in technology, working toward finding the “right” method to economically extract the gas. Federal funding of research in the 70s and 80s aided Mitchell in the development of fracking technology. This technological breakthrough laid the foundation for the shale gas boom currently occurring in the U.S. Figure 1 below shows a schematic of the hydraulic fracturing process.

Many current policy concerns about hydraulic fracturing center around the transportation and disposal of large volumes of fresh water needed in the process. However, efforts are underway to reduce the amount of water as well as use of lower-quality waters, such as brackish or treated sewage effluent mixed in varying with fresh water. Furthermore, research is underway to virtually eliminate water by using such substitutes as propane and solid propellants to fracture rock, which may eliminate water issues but raise others as more becomes known about the impacts of these alternatives. Discussion in this report is limited to current hydraulic fracturing issues.

FIGURE 1: Schematic of Hydraulic Fracturing (U.S Department of Energy, 2011)



Steel casing lines the well and is cemented in place to prevent any communication up the wellbore as the fracturing job is pumped or the well is produced. Shallow formations holding fresh water that may be useful for farming or public consumption are separated from the fractured shale by thousands of feet of rock.

CURRENT STATUS

Tapping new reserves of energy through the use of new fracking techniques has been somewhat controversial, as consensus has not been reached on its environmental impacts. Natural gas, the product of fracking, burns cleaner than petroleum-based fuels. Its lower levels of carbon allows natural gas vehicles to emit lower levels of greenhouse gases (GHGs) like carbon dioxide and carbon monoxide. The Alternative Data Fuels Center reports that, “natural gas emits approximately 6% to 11% lower levels of GHGs than gasoline throughout the fuel life cycle” (U.S. Department of Energy, 2014f). The increased use of natural gas in power plants has also reduced dependence on coal, providing important environmental benefits.

A 2014 study by the National Oceanic and Atmospheric Association found that the increasing use of natural gas in power plants in the U.S. has led to a 23% lower emissions rate of carbon dioxide (Massaro, 2014). Overall, GHG emissions in the U.S. have declined by 10% from 2005 to 2012, with a 3.4% reduction from 2011 to 2012, attributed partly to greater reliance on natural gas over coal (Volcovici, 2014). Despite these benefits, environmental impacts of the extraction and processing of natural gas continue to spark debate about its overall benefits. Some studies have found that methane gas leakages during fracking are counteracting the benefits of carbon dioxide emissions reductions. Additionally, there are concerns over water contamination in areas where fracking occurs. Many green energy advocates also worry that increases in production of natural gas will lead to a slowing down of investment in renewable energy.

National security and energy independence are also affected by this "new" resource. Through increased production and use of natural gas, the U.S. has the opportunity to move toward self-sufficiency and away from dependence on Middle East and OPEC-state energy production. The increase in production allowed by fracking techniques would also decrease fuel price volatility, resulting in a more stable energy market and could lead to an "in-sourcing" of jobs back into the U.S., a factor often highlighted by advocates of fracking.

But calculating the impact of job creation related to the fracking boom is a difficult task, as domestic production has produced both direct and indirect jobs. Pennsylvania, which increased its natural gas production by 72% from 2011 to 2012, has experienced as 360% increase in oil and gas industry jobs from 2002 to 2012 while the rest of the state saw a 1.3% increase in jobs. It is important to note, however, that jobs in natural gas production in Pennsylvania accounted for less than 1% of the state's total jobs (Foran, 2014). The state of Texas saw the largest increases in oil and gas industry jobs in the U.S. during 2012, adding 43,000. Texas oil and gas job growth was estimated to account for more than half of all domestic oil and gas job growth in the first half of 2013 (TIPRO, 2013). It is clear that, while determining the impact of both direct and indirect employment growth as a result of fracking and natural gas production is complex, its role in Texas energy and transportation sectors will continue to be significant.

Access to a wide number of shale gas plays has increased over the past fifteen years and the available supply has followed suit. As Figure 2 shows, the U.S. is home to numerous prospective and currently tapped shale gas plays. In the year 2000, shale gas accounted for 1% of the domestic supply. By 2011, shale gas was 25% and is continuing to grow. More recent figures show that shale gas currently accounts for one-third of the U.S. natural gas supply, and current

estimates suggest the U.S. has reserves that will last for 110 years (International Energy Agency, 2012). The U.S. Energy Information Administration's *Annual Energy Outlook* for 2014 has projected shale and unconventional oil production to peak in 2021 at 4.8 million b/d, or 51% of total U.S. crude output (U.S. Energy Information Administration, 2014a).

FIGURE 2: North American Shale Gas Plays
(Source: U.S. Energy Information Administration, 2011)

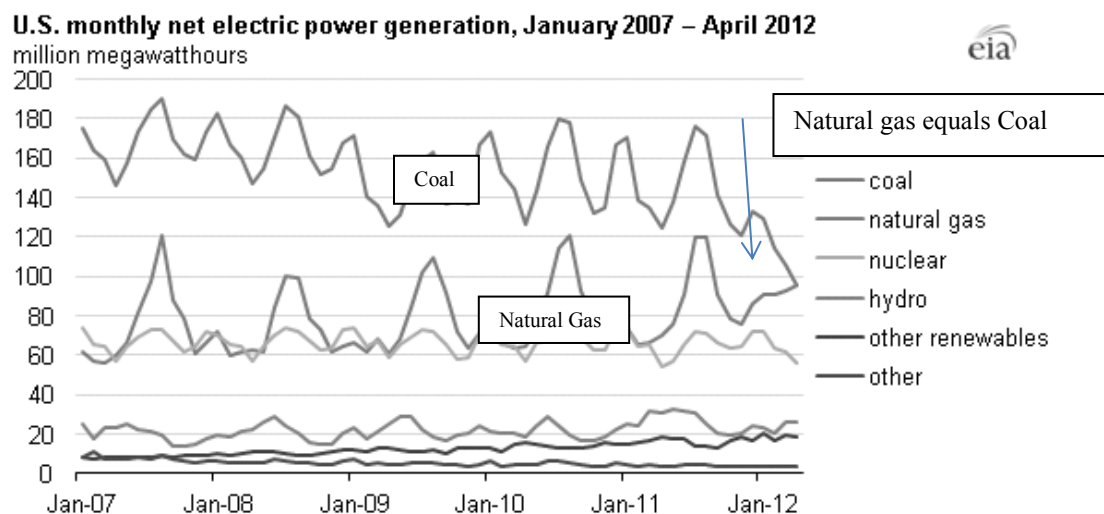


According to RBC Capital Markets, a prominent Canadian investment bank, “the percentage of all U.S. wells accounted for by the Big Four plays is also forecast to rise, accounting for 58% this year [2013], 62% next year [2014] and 63% in 2015” (Spencer, 2014).

Fracking operations in and around Texas are likely to continue expanding. Pioneer Natural Resources, the operator of the Permian shale play in west Texas, estimates close to 10,000 potential undrilled wells. Pioneer will accelerate its spending in the Permian basin. The Tuscaloosa Marine Shale is an emerging play in the Louisiana and Mississippi region where recent horizontal drilling has been taking place (Spencer, 2014). Analysts from Barclays Capital, a UK-based investment bank, have noted that new technology and the growing fracking inventory in the U.S. point to activity levels rising by double-digit percentages over the coming years. Improvements in drilling efficiencies will continue to drive drilling in South Texas.

Fracking technological advances have produced an abundance of natural gas, leading to lower prices and greater access to new markets. How the U.S. decides to utilize this energy by re-thinking its current energy policy will have far reaching national and global energy and economic implications. Numerous factors affect the U.S.'s opportunity to utilize this new technology to spur domestic production, growth and long-term commercialization.

FIGURE 3: U.S. Monthly Electric Power Generation 2007-2012
(Source: US EIA, 2012)



For the first time in decades, the U.S. has the opportunity to become the largest producer of natural gas, with the possibility of becoming a net exporter of energy. Figure 3 highlights the rapid growth in natural gas in the energy sector. Within the U.S., the energy landscape has changed; as of April 2012, natural gas for the first time equaled coal as the primary fuel sources for electric generation, with both at 32% (U.S. Energy Information Administration, 2012).

The changing landscape of natural gas is not only transforming the way we view our energy generation, but has also been fueling a reevaluation of our nation's transportation system. President Obama spoke of natural gas three times in his 2013 State of the Union Address, stating, “We produce more natural gas than ever before -- and nearly everyone’s energy bill is lower because of it. And over the last four years, our emissions of the dangerous carbon pollution that threatens our planet have actually fallen” (Obama, 2013). There is no question that fracking has unleashed numerous opportunities for the U.S., as Obama's speech highlighted the benefits of increased production of natural gas.

In February 2014, President Obama called for his administration to implement new fuel efficiency standards for medium and heavy-duty commercial trucks. The deadline for this action was set for early 2016. These new and tougher standards are part Obama’s climate strategy focus in his second term in office. The proposed changes will be jointly developed by the EPA and the U.S. Department of Transportation. This new focus on fuel efficiency has also been touted as a means to reduce foreign oil dependence (Lee et al., 2014). With domestic supply of

natural gas increasing steadily and the emissions reduction benefits of natural gas, it is likely that natural gas production and infrastructure will continue to be a focus of federal initiatives and private industry.

Recent federal action by the EPA and Congress also suggest that focus is shifting away from other alternative fuel funding, which may mean a greater opportunity for natural gas investments. In 2014, 80% of biodiesel producers scaled back their production, while more than half have idled production. A National Biodiesel Board survey found these scale reductions to be a result of a “weak” Renewable Fuel Standard (RFS) proposal by the Environmental Protection Agency (EPA), as well as Congress’ failure to extend tax incentives for biodiesel. The RFS proposal by the EPA signifies a deep reduction in production. With these cuts in production and resulting reduced availability of biodiesel, trucking companies and fleets may react with greater investments in natural gas vehicles (Transport Topics, 2014).

The effects of the natural gas boom reach beyond the border of the U.S. and have begun to impact the international market. The International Energy Agency’s *World Energy Outlook* for 2012 suggested that, because of the shale boom, the U.S. would overtake Saudi Arabia and Russia to become the world’s largest oil producer, and as soon as 2015 would surpass Russia as the largest producer of natural gas (International Energy Agency, 2012). PIRA, a U.S. Energy consultancy, reported in October 2013 that the U.S. had become the world’s largest oil producer, meeting IEA projections (Reuters, 2013b). In addition, the U.S. produced 29,542 billion cubic feet (BCF) of natural gas in 2012, while Russia produced 23,053 BCF (U.S. Energy Information Administration, 2014b). The rapid expansion of natural gas capabilities has caused a shift in the way the U.S. and the rest of the world view energy.

NATURAL GAS VEHICLES

Historically, natural gas has been used for residential and industrial needs. Globally, however, the natural gas vehicle (NGV) market has allowed natural gas to expand into the transportation sector. Recent technological advances in natural gas extraction have allowed the U.S. to view natural gas as a viable alternative to liquid petroleum. NGV numbers have almost doubled in the past decade with around 20% of city transport buses utilizing the fuel. The U.S. is home to around 120,000 NGVs, a small percentage of the worldwide total of around fifteen million (Natural Gas Vehicles for America, 2011). Although the U.S. has only slightly more than 1% of the world's NGVs, fracking is providing the abundance of natural gas needed to boost our rate of adoption and acceptance of NGVs. Table 1 shows the top-ten countries with natural gas vehicle populations, with Iran and Pakistan leading with 18.8% and Thailand at the bottom, with 2%. The U.S. is added to the bottom of the table for comparison. Currently home to 1.22%, the U.S. is significantly behind most of the world where adoption of NGVs is widespread and expected to grow, especially in developing nations.

TABLE 1: Natural Gas Vehicle Populations
(Source: Natural Gas Vehicles for America, 2011)

Rank	Country	NGV Population	% of NGVs in World
1	Iran	2,859,356	18.80%
2	Pakistan	2,850,500	18.80%
3	Argentina	1,900,000	12.50%
4	Brazil	1,694,278	11.20%
5	India	1,100,000	7.20%
6	China	1,000,000	6.60%
7	Italy	779,090	5.10%
8	Ukraine	390,000	2.60%
9	Colombia	348,747	2.30%
10	Thailand	300,581	2.00%
*	United States	123,000	1.22%
	Total	13,345,552	88.32%

VEHICLE TECHNOLOGY

As Table 1 suggests, natural gas vehicles have been adopted worldwide and the existing technology is far from its infancy. Natural gas engines can come in all shapes and sizes and are being utilized in passenger cars, waste haulers, buses, taxis and large long-haul trucks. NGV technology offers advantages over conventional fueled vehicles by offering multiple options based on driving needs. There are three different types of NGVs currently being manufactured: Dedicated, which run solely on natural gas; Bi-fuel, which run on natural gas and gasoline, utilizing a dual fueling system; and Dual-Fuel, which run on both natural gas and diesel. These three engine types are fueled by natural gas, in either compressed natural gas (CNG) or liquefied natural gas (LNG) form. Both forms are considered alternative fuels under the Energy Policy Act

of 1992 (U.S. Department of Energy, 2013a). The Dedicated NGV engine allows customers with access to NGV fueling stations the option of taking advantage of lower natural gas prices, while both the Bi-Fuel and Dual-Fuel engines provide consumers with the option of fueling up with natural gas when it is available or more traditional fueling options when it is not. The latter engine options are particularly advantageous because they allow consumers more options and, therefore, more control over their energy use and costs.

Large-scale adoption of NGV technology must rely on a steady market of vehicles. There are a wide variety of light-duty and heavy-duty NGVs currently on the market, including conversion kits to retro-fit existing gasoline and diesel engines. There is also an expanding market of new production engines geared toward the heavy-duty truck market. Table 2 shows that, according to the *Guide to Available Natural Gas Vehicles and Engines*, there are numerous manufacturers who are currently supplying the heavy-duty market with NGVs. The table is broken down by manufacturer, engine-type, application, ranging from school buses to heavy-duty long-haul trucks, and emission certification type.

TABLE 2: Manufacturers of Natural Gas Engines
(Source: Argonne National Laboratory, 2010)

Manufacturer	Engine Type	Application	Certification
Cummins Westport, Inc.	5.9-L B Gas Plus (sparkignited)	Medium-duty (e.g., school buses/shuttles); production ended 12/31/09	EPA 2007 compliant (0.01 g/bhp-h PM)
Cummins Westport, Inc.	8.9-L ISL G (sparkignited)	Heavy-duty (e.g., refuse, transit/school buses, street sweepers, yard hostlers)	EPA/CARB 2010 compliant (0.2 g/bhp-h NO _x and 0.01 g/bhp-h PM)
Doosan Infracore America Corp.	11-L GK12-C (sparkignited)	Heavy-duty (e.g., refuse trucks and transit buses)	EPA/CARB 2007 compliant (0.01 g/bhp-h PM)
Doosan Infracore America Corp.	11-L GK12-S (sparkignited) w/SCR	Heavy-duty (e.g., refuse trucks and transit buses)	EPA/CARB 2010 compliant (0.01 g/bhp-h PM)
Emission Solutions, Inc.	7.6-L NG Phoenix (sparkignited); remanufactures the Navistar International MaxxForce DT diesel platform to natural gas	Medium-duty (e.g., school buses/heavyduty cutaway shuttles and work trucks)	EPA/CARB 2010 compliant (0.2 g/bhp-h NO _x and 0.01 g/bhp-h PM)
Westport Innovations	15-L GX (compressionignited) dual-fuel high pressure direct-injection (95% natural gas, 5% diesel)	Heavy-duty (e.g., work trucks and line-haul applications)	EPA/CARB 2010 compliant (0.2 g/bhp-h NO _x and 0.01 g/bhp-h PM)

There have been several recent developments in vehicle technology for natural gas trucks. “There continues to be breakthroughs in technology, leading to increased purchases and orders for natural gas vehicles across the trucking industry, evidence that natural gas is ‘not just a passing fad’” (Malloy, 2014a). Among these are companies like Mack, Volvo, Freightliner, Kenworth and Peterbilt – all of which have developed recent Class 8 compressed natural gas (CNG) and liquefied natural gas (LNG) engine models (Malloy, 2014e). Volvo Trucks is targeting a 2015 release of a newly designed 15-liter LNG engine, which will perform similar to a diesel engine. The model will use high-pressure direct-injection technology which utilizes a small amount of diesel fuel. Frank Bio, Volvo’s Director of Specialty Vehicles and Alternative Fuels noted that, “We think LNG will begin to move forward as a result of this engine” (Malloy, 2014d). In addition to Volvo, Cummins Westport’s 12-liter natural-gas engine, the ISX12G, has experienced growth in popularity.

Chart Industries, a supplier of large-scale LNG storage tanks, notes that the LNG market in the U.S. has been steadily increasing. New developments in tank design are allowing for more economical on-board storage for trucks (Malloy, 2014d). 3M CNG tank designs, released in 2013, are 30% lighter and have up to 10% more storage capacity than current systems. They have partnered with Rush Enterprises, a materials-technology company, to design, manufacture, and install these new tanks in trucks classes 6-8 in the North America (Malloy, 2014d). These advancements in engine technology and tank systems have allowed natural gas trucks to have more streamlined designs and allow for tighter turning radiuses on some models, both of which significantly impact fuel economy and efficiency.

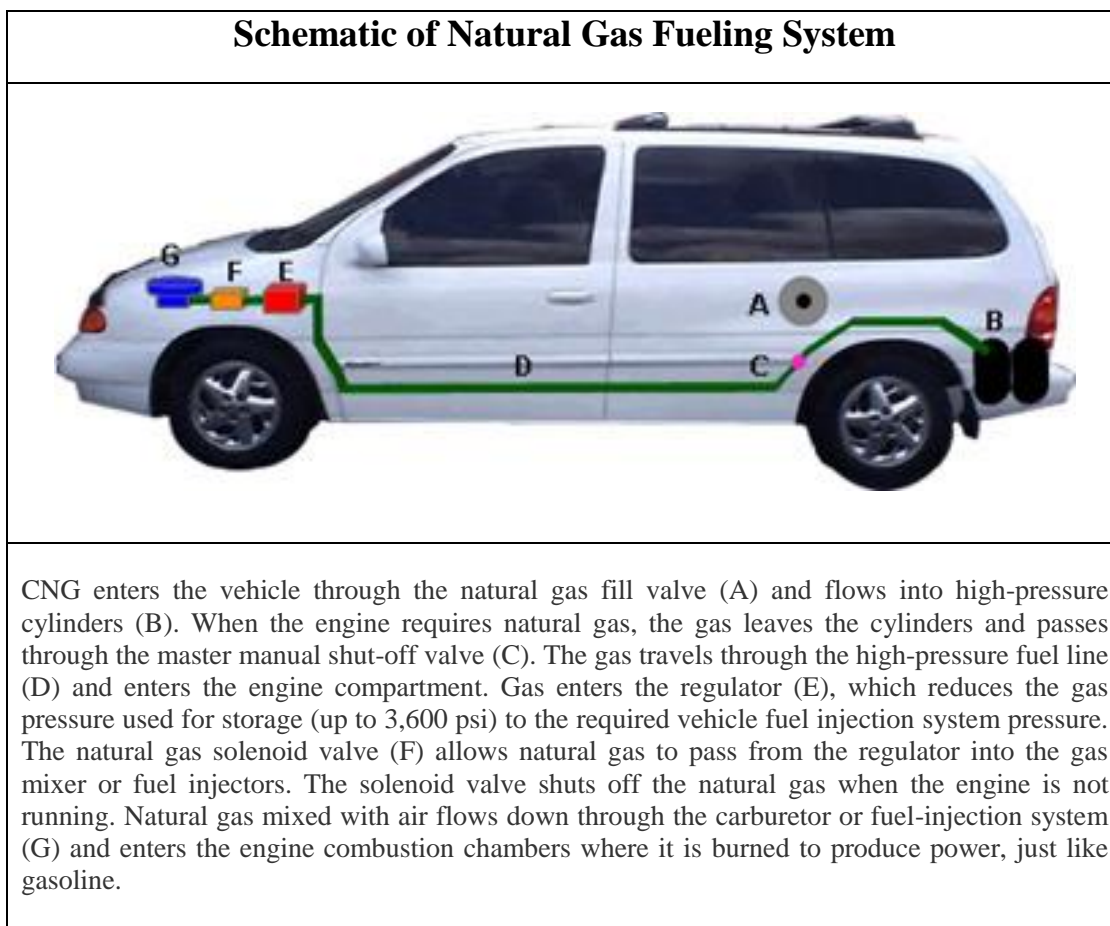
FUELING SYSTEM

As natural gas comes in a gaseous form, it must be stored either through compression (CNG) or the process of being liquefied (LNG). CNG is stored in cylinders up to 3,600 pounds per square inch, while LNG must be cooled to -260⁰F and stored in double-walled tanks (Argonne National Laboratory, 2010). Of the deciding factors of NGV adoption, tank storage space and vehicle range are paramount. CNG storage tanks are heavier, require more space, and are less energy dense than LNG, thus often utilized by smaller passenger vehicles (like the Honda Civic GX) and fleet vehicles, which have shorter ranges and utilize a central charging station. LNG requires 30% less tank space than CNG is mainly used in larger long-haul trucks, which allows for an increased range and is able to deliver the increased energy density needed for heavy loads (Natural Gas Vehicles for America, 2013).

Refueling NGVs is very similar to current conventional forms of fueling vehicles. CNG, for example, can be fueled by a fast-fill or a time-fill system. Both systems pull natural gas off the existing infrastructure. While the fast-fill system uses a large compressor and stores the compressed gas in a high-pressure tank, which is then transferred to the vehicle via a pump, similar to fueling a conventional vehicle. The time-fill system, which can be used by residential customers, relies on a smaller compressor and does not use a storage tank rather it slowly pressurizes the gas and fills the tank directly. LNG requires more storage space as it is stored in special cryogenic tanks and usually delivered liquefied, and is pumped like any other liquid fuel (Natural Gas Vehicles for America, 2013). Although both fueling options can be accessed at

"gas stations" similar to the conventional fuel stations, the nozzles and vehicle receptors form a sealed system, which differs from the current conventional stations and pumps (Argonne National Laboratory, 2010). Figure 4, provides a schematic of a natural gas fueling system.

FIGURE 4: Schematic of Natural Gas Fueling System
(Source: U.S. Dept of Energy, 2013a)



FUELING INFRASTRUCTURE

The Alternative Fuels Data Center (AFDC) at the U.S. Department of Energy tracks the current available and planned fueling stations across the U.S. As of 2013, there were 67 LNG stations in the U.S., though only 28 were accessible by the public. CNG vehicles were more widely available with a total of 1,204 stations with 574 open for public consumption (U.S. Department of Energy, 2013a). The AFDC website provides lists and locations of the natural gas refueling stations and even allows users to map out a route utilizing the current facilities. The ability to map out routes is beneficial to natural gas users but it serves to highlight the “range anxiety” problem that has plagued alternative fueled vehicles.

The following example highlights the issue of range anxiety. There are 29 CNG stations along the route from Austin, Texas to Los Angeles, California. On the surface, this route appears to offer numerous options for re-fueling needs. However, one would have to travel from Austin, Texas to Tucson, Arizona (894 miles) before being able to re-fuel. Of the 29 stations, the vast majority are located in the Los Angeles vicinity.

Stations that are currently operating are scattered across the country, but the majority are in California, which has historically embraced alternative fuel vehicles (AFVs), along with energy rich states like Texas and Oklahoma. The scattering of fueling centers leads to a regional disparity in the ability to utilize natural gas as a transportation fuel, as many fueling facilities are regionally clustered.

But these infrastructure limitations may be changing. In addition to Clean Energy Fuel Corp., Shell Oil, Questar Fueling Co., TruStar Energy, and Blu LNG have all recently opened or expanded fueling stations in the US. In California, TruStar Energy is looking to add 40-50 stations in 2015 throughout the state. Wisconsin-based U.S. Oil is aiming to add 100 new CNG sites within three years. Questar Fueling Co. currently owns a CNG station in DeSoto, Texas and is planning for two more stations in the state. Love's Travel Shops also plans to add 11 fast-fill CNG stations, most in or near Texas. This growth in infrastructure in strategic areas of the U.S. will only help to foster growth in adoption of natural gas for the trucking industry, as range anxiety becomes less of a barrier (Malloy, 2014e).

As the number of natural gas fueling stations increases, the fueling infrastructure is still facing what many refer to as the "Chicken and Egg dilemma." The average construction cost of \$1.5 million per fueling station can be cost prohibitive and infrastructure will not be built unless there is a strong customer base utilizing the fuel (Deal, 2012). On the other hand, long-haul trucks and locally fueled fleets may still be wary to purchase costly natural-gas-fueled vehicles without having the needed fueling infrastructure in place.

The customer base in the U.S. is growing, as large companies are focusing more on natural gas vehicle investments for their fleets. UPS has placed focus on building fueling infrastructure as well as expanding their natural gas fleet. The company is implementing plans to build 15 new LNG fueling stations by the end of 2014. In addition to their fleet of 220 LNG tractors, the company will likely have 1,000 running within the same time frame (Malloy, 2014a).

Other companies have looked to partnerships with natural gas producers to expand their investments in natural gas trucks. Kroger Co., a major grocery chain, announced at the May 2014 Alternative Clean Transportation Expo their recent LNG fueling contract with Clean Energy Fuels Corp. in the Portland, Oregon area. Kroger Co. currently has a 1,200 tractor fleet and 1,800 third-party carriers, and will be using 40 new LNG trucks in Portland, being the first fleet in the state to run on LNG (Malloy, 2014d).

Companies like PepsiCo and Owens Corning have also made strong commitments to investing in natural gas fleets. Replacement units for PepsiCo are currently 90% natural gas trucks, and Owens Corning estimates that 10% of the 140 million miles travelled in the first half of 2014 have been via natural gas (Malloy, 2014d). J Rayl Transport, an Ohio-based trucking company,

is currently converting approximately 50% of their 250-truck fleet to natural gas. The main motive for this transition is to cut fuel expenses and cut emissions. The trucks have a 165 diesel-gallon-equivalent (DGE) tank capacity and run in regional as well as long-haul trips, including successful routes between Akron, Ohio and Texas, Georgia and Oklahoma (Malloy, 2014a).

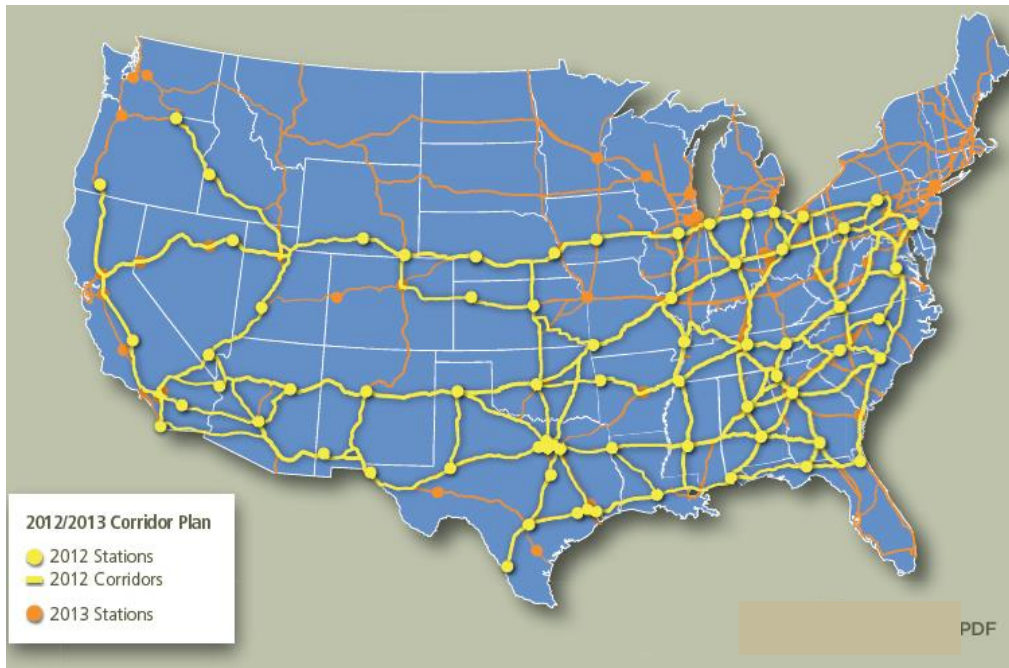
Analysis of current natural gas trends in the U.S. trucking industry show promise for continued growth in the future. Customers of Clean Energy Fuel Corp. ordered 70% more natural-gas-powered vehicles in the first nine months of 2013 from the same period in 2012 (Transport Topics, 2013b). And the Alternative Clean Transportation Research Co. predicts a steady growth in natural gas trucking trends into 2015 and beyond (Malloy, 2014g).

CASE STUDY: CLEAN ENERGY FUELS

Clean Energy Fuels Corp., one of the largest providers of natural gas transportation fuel in North America, is investing in solving the infrastructure problem. The Oklahoma City-based company, co-founded by T. Boone Pickens, has been investing in fueling stations to expand the natural gas vehicle fueling market. Currently, the company provides fueling stations for over 530 fleet customers and 25,000 vehicles in the refuse, transit, trucking, shuttle, taxi, airport and municipal fleets that mainly utilize CNG vehicles. Clean Energy also owns multiple natural gas technology companies and LNG production plants, which mainly serve the heavy-duty truck market. The company owns 96 fueling stations, 14 of which are exclusively LNG, and 11 provide both fuel types (Clean Energy Fuels Corp., 2013).

In direct response to the chicken and egg issue, the company has been building what has been called “America’s Natural Gas Highway,” as seen in Figure 5. As of 2013, this network of 150 LNG truck-fueling facilities stretched from coast to coast in strategic locations to facilitate long-haul trucking needs. Clean Energy Fuels has made strategic partnerships with natural gas-fueled truck manufacturers, as well as Pilot Flying J stations, which will allow for the use of pre-existing stations and existing routes (Clean Energy Fuels Corp, 2013). CNG fueling options are available but “The Natural Gas Highway” is marketed toward heavy-freight trucking, for which LNG is better suited.

FIGURE 5: Clean Energy Fuels: America's Natural Gas Highway 2012-2013
(Source: Clean Energy Fuels Corp, 2012)



Clean Energy is positioned to benefit from the increase in domestic natural gas production in the U.S. Its entry into the market and the ability to provide, in many cases, up-front investment and technology to retrofit existing conventional stations significantly changes the natural gas fueling landscape. This changing landscape of increasingly available fueling options is encouraging manufactures, retailers, and consumers to examine natural gas as a viable alternative to conventionally liquid petroleum-fueled vehicles.

Analysts also predict that the low fuel prices for natural gas may affect the shipping market for rail intermodal trailer and container transport (intermodal). This may shift some freight transport back to truckload service. Jason Kuehn, a surface transportation consultant with Oliver Wyman, noted that truck shipping may be the more economical choice for distances as long as 750 miles. This is likely to have a more dramatic impact on competition between trucking and intermodal in the eastern U.S., as intermodal has been growing the most rapidly in that region. But throughout the U.S., intermodal shipping continues to break records. According to the Association of American Railroads Statistics, intermodal accounts for more than 40% of rail shipments and will continue to grow faster than GDP. In June 2014, the Union Pacific Railroad opened a terminal facility in New Mexico near the Mexican border. This is likely to impact shipping competition through the region, particularly if the lower prices of natural gas continue to be an economic draw for truckload shipping (Watson, 2014).

NGV ADOPTION FACTORS

Adoption of NGVs by the private and public sectors revolve around price. The initial price of adoption, fuel prices and return on investment (ROI) in the technology depend most importantly on price differential. Differences between the conventional diesel-powered vehicles and NGVs provide insight into adoption factors. This section expands on the adoption decision factors, including energy density, vehicle prices, and fuel prices.

ENERGY DENSITY

Natural gas has the ability to fuel numerous types of vehicles but it stands to make the most inroads into the long-haul truck and fleet vehicle market. Deciding to run NGVs greatly depends on the function of the vehicle and the fuel energy density needs to accomplish that function, versus conventional diesel. CNG has about 25% of the energy density of the diesel equivalent, while LNG has approximately 60%. This means that trucks running on natural gas often carry larger or a greater number of tanks than would be required by diesel. Comparatively, however, LNG has about 2.4 times more energy per diesel-gallon-equivalent (DGE) than CNG (Sylvester-Chaudhuri, 2013). Generally, LNG is used in heavy-duty, long-haul truck applications as the energy density required for hauling heavier loads and maintaining a comparable range to diesel is met. LNG also refuels at a comparable speed to diesel, while CNG requires compression which can lengthen refueling time. CNG, on the other hand, lends itself to smaller light-duty and medium-duty vehicles which do not have the same energy density and fueling requirements (Nijboer, 2010).

As natural gas truck and engine design, fueling systems, and storage systems have evolved, the early-established applicability of CNG and LNG may be changing. The emergence of “fast-fill” technology at fueling stations has brought into question whether or not LNG is the best option for long-haul trucks. And companies investing in infrastructure are driving this debate.

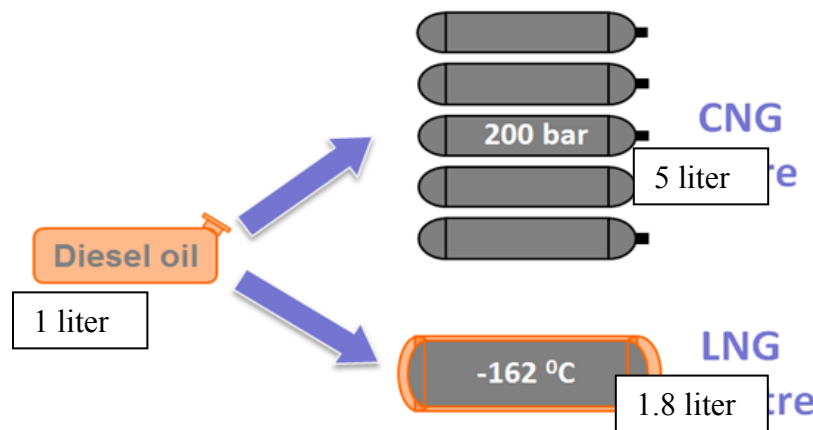
CNG is pulled directly from existing natural gas pipelines, and is compressed and pumped into vehicles like conventional fuel. Trillium CNG, a Chicago-based investment firm, has been one of the leaders in natural gas infrastructure development. It plans to expand its network of CNG stations to over 30 states, and is focusing on the development of fast-fill CNG fueling stations intended for heavy-duty Class 8 trucks. The company argues that, “it is a cheap, simple and safe way to transport and store natural gas” (Sylvester-Chaudhuri, 2013). CNG is also less expensive to produce than LNG, and Trillium’s general pricing model also shows a \$.48 per gallon cost savings for CNG over LNG. New CNG infrastructure is, however, limited by the placement of existing pipeline infrastructure. There are also significantly greater electricity demands at fast-fill CNG stations, due to the compression process.

LNG must be cryogenically cooled to a liquid state, and is often transported by tanker trucks (though it can be pulled from natural gas pipelines where there is access). The refueling process also requires drivers to wear protective equipment to prevent burns. Clean Energy Fuels Corp. has made significant investments in LNG infrastructure in the U.S. to meet the needs of the long-haul trucking industry, including two LNG cooling facilities. Despite the greater cost in

production and shipping of LNG, stations have more geographic flexibility and require less electricity.

Private investment in both CNG and LNG infrastructure, along with continued advances in natural gas technology, will likely continue to affect the adaptability of fuel options for small to heavy-duty vehicles.

FIGURE 6: Volumetric Equivalence between Diesel, CNG and LNG
(Source: Natural Gas Vehicles Association Europe, 2013)



Source: NGVA Europe

As Figure 6 shows, the physical space needed to hold and carry the CNG and LNG differ. LNG is mainly used in long-haul trucking capacities as it delivers about the same energy output as conventional diesel.

FUEL PRICES

When natural gas is sold as a transportation fuel, it is sold in diesel-gallon-equivalents (DGEs), which take into consideration the differing energy densities. The price per gallon of natural gas is generally lower than gasoline. The April 2014 *Clean Cities Alternative Fuel Price Report* from the U.S. Department of Energy noted that natural gas prices nationwide were on average \$1.25 less than gasoline, and \$1.80 less than diesel (U.S. Department of Energy, 2014e). The report also highlights CNG prices compared to diesel throughout the U.S., with the biggest price gaps in the Rocky Mountain region. Regional differences are displayed in the figure and table below (U.S. Department of Energy, 2014e).

FIGURE 7: Price Differentials by State for CNG Relative to Diesel
(Source: U.S. Department of Energy, 2014e)

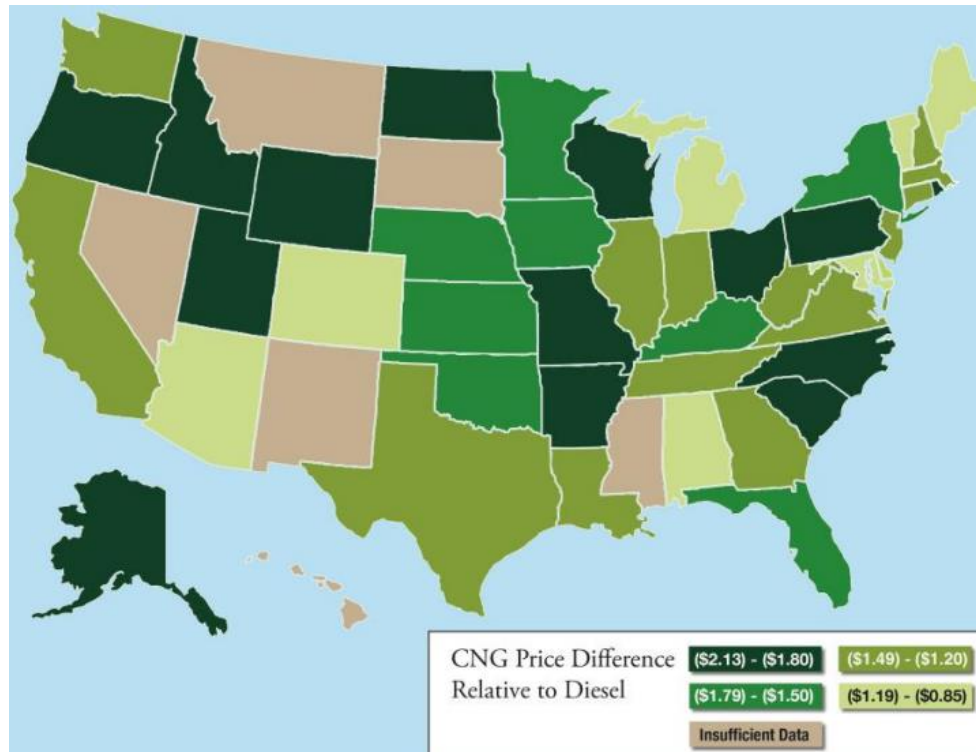


TABLE 3: Compressed Natural Gas and Diesel Average Prices by Region
(Source: U.S. Department of Energy, 2014)

	Natural Gas (CNG) Information Reported by Clean Cities (\$/DGE)		Diesel Information Reported by Clean Cities (\$/gal)	
	Average Price	Number of Data Points	Average Price	Number of Data Points
New England	\$2.87	28	\$4.32	35
Central Atlantic	\$2.41	101	\$3.90	52
Lower Atlantic	\$2.31	36	\$3.97	30
Midwest	\$2.32	80	\$3.91	74
Gulf Coast	\$2.36	33	\$3.80	16
Rocky Mountain	\$2.08	102	\$3.91	33
West Coast	\$2.64	113	\$3.97	94
NATIONAL AVERAGE	\$2.40	493	\$3.97	334

As the following figures suggest, the 2008 recession caused a shift in the way the oil and natural gas markets correspond to each other. Prior to the 2008 recession, the prices fluctuated in much the same manner.

FIGURE 8: Henry Hub Natural Gas Prices (Source: CME Group, 2013)



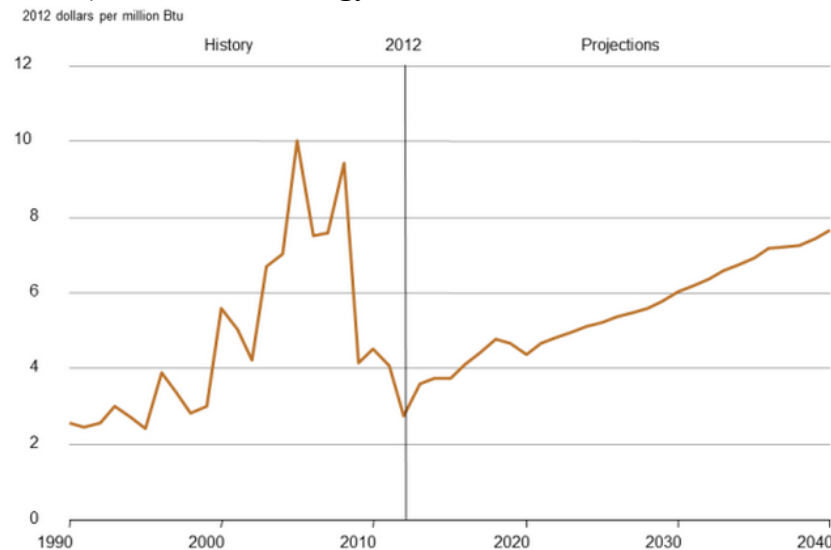
FIGURE 9: Light Sweet Crude Oil (WTI) Prices (Source: CME Group 2013)



The National Conference of State Legislatures' *Transportation Energy for the Future* suggests that, prior to 2008, the fluctuations in prices of natural gas, which were then tied to the fluctuations in oil, were a large reason why the technology had not been adopted on a large scale. The report further suggests that the increase in domestic supply has been a determining factor in leveling the price volatility (National Conference of State Legislatures, 2012). As Figure 9

suggests, natural gas prices, although expected to rise, offer a much more stable price compared to oil following the 2008 recession.

FIGURE 10: Annual Average Henry Hub Natural Gas Prices Forecast through 2040 (Source: U.S. Energy Information Administration, 2014a)



The U.S. Energy Information Administration's *Annual Energy Outlook* for 2014 projects future natural gas prices to remain stable through their 2040 forecast, rising by an average of 3.7% per year. This increase is mainly a result of production costs, as natural gas recovery moves into areas of shale plays where extraction is more difficult, and ultimately more costly. Still, the stability and lower price versus conventional fuels offers NGV adopters the opportunity to lock in fuel prices to mitigate price spikes, allowing for greater ability in forecasting, and allow for greater return on investment accuracy.

The 2014 report also shows projections for natural gas consumption by industry in the U.S. “Although transportation use currently accounts for only a small portion of total U.S. natural gas consumption, natural gas use by heavy-duty vehicles (HDVs), trains, and ships shows the largest percentage growth of any fuel in the projection” (U.S. Energy Information Administration, 2014a) Continued investment in NGV technology and infrastructure, along with overall price stability, speak to a greater adoption of natural gas in trucking in both the U.S. and abroad.

TRUCK PRICES

The price of natural gas trucks can range anywhere from \$30,000 to \$70,000 more expensive per vehicle than comparable diesel trucks (Deal, 2012). While natural gas engine prices are decreasing as more manufactures are exploring the market, stricter emission standards are increasing the cost of conventional diesel engines (Argonne National Laboratory, 2010). Nevertheless, with a considerable up-front vehicle cost, fuel prices are critical for adopters to see

a return on that investment. Table 3 provides a snapshot of the vehicle type, fuel utilized, and estimated annual fuel cost savings by comparing CNG or LNG versus gasoline or diesel.

TABLE 4: Representative Annual per Vehicle Fuel Cost Savings by Fleet Market for California Based on Average Fuel Prices During 2013
(Source: Clean Energy Fuels Corp, 2013)

Market	Fuel	Estimated annual fuel usage (gallons)	Cost of fuel CNG or LNG vs. gasoline or diesel (gallons)	Estimated annual fuel cost savings
Taxi	CNG vs. Gasoline	5,000	\$2.85 vs. \$3.89	\$ 5,200
Shuttle van	CNG vs. Gasoline	7,500	\$2.85 vs. \$3.89	\$ 7,800
Municipal transit bus (CNG)	CNG vs. Diesel	16,680	\$1.53 vs. \$3.06	<u>\$25,520</u>
Refuse truck (CNG)	CNG vs. Diesel	11,120	\$1.47 vs. \$3.71	<u>\$24,909</u>
Municipal transit Bus (LNG)	LNG vs. Diesel	16,680	\$1.46 vs. \$3.06	<u>\$26,688</u>
Refuse truck (LNG)	LNG vs. Diesel	11,120	\$1.81 vs. \$3.71	<u>\$21,128</u>
Heavy-duty truck (LNG)	LNG vs. Diesel	20,000	\$2.63 vs. \$3.71	<u>\$24,019</u>

Current natural gas prices versus the conventional diesel fuel have allowed the NGV market to take advantage of price disparities. When taking into consideration the up-front investment of purchasing NGVs, an IHS Cambridge Energy Research Associates (CERA) report suggests adopters could see a positive return on investment in as little as three years without government incentives (HIS CERA, 2012). While the up-front cost of vehicles continues to be an issue for companies looking to add natural gas trucks (particularly for smaller truck companies with less access to capital), private partnerships have emerged with the aim to reduce up-front costs for natural gas infrastructure and fleet investment. Clean Energy Fuels Corp. aligned itself in 2014 with GE Capital Finance to be able to offer financing assistance for fleets that buy 75% of their natural gas from Clean Energy during their lease (Malloy, 2014a).

The question whether or not to adopt depends heavily on the availability of cheap natural gas and the purpose of the vehicle purchased. The following examples offer insight into two types of adopters, long-haul trucks and fleet vehicles.

CASE STUDY: LYNDEN INC.

As part of the National Energy Policy Institute (NEPI), *What Set of Conditions Would Make the Business Case to Convert Heavy Trucks to Natural Gas*, Lynden Inc. Transportation Company participated in a study to examine economic and operational conditions that would lead to private investment in natural gas trucks. The model accounts for fuel price, weight differential, fuel economy, operational range, price differential, depreciable life, salvage value, and maintenance costs versus conventional diesel trucks. The case study uses a profit-and-loss model in calculating cost of savings per mile, per truck and per fleet, based on a 20% return on investment (ROI) for Lynden Inc. (Deal, 2012). Table 4 highlights the key finding of annual miles per truck and truck range of the case study, categorized from very profitable, marginally profitable, and not profitable.

TABLE 5: Operational Characteristics: Lynden Inc. Case Study at \$1.50 Diesel Gallon Equivalent (Source: Deal, 2012)

Very Profitable	-Annual miles per truck > 90,000 miles -Range is < 450 miles
Marginally Profitable	-Annual miles per truck is 60,000 – 90,000 -Range between fueling is 450-750 miles
Not Profitable	-Annual miles per truck is < 60,000 miles -Range between fueling is > 750-800 miles

The model concluded that, to achieve the 20% ROI, required Lynden Inc. to invest in the “high perceived risk” natural gas trucks, Fuel price and annual range driven were key factors. The model found the critical point in the price per gallon differential between natural gas and diesel to be between \$1.25 and \$1.50 (Deal, 2012). It was at that point that the 20% ROI was achieved, for a large percentage of the truck fleet. When the price differential increased above \$2.00, trucks that traveled fewer annual miles were also able to meet the 20% ROI. The model also found a lower limit of trucks that traveled less than 20,000 miles annually, or when the price differential was less than \$0.75, the desired ROI was unattainable (Deal, 2012). Although the case study cautions using the Lynden model with other firms, citing differences between the needs of trucking firms, the model provides insight into determining factors of adopting natural gas trucks.

FLEET VEHICLES

Dallas Area Rapid Transit (DART) unveiled its new compressed-natural-gas bus fleet on January 28, 2013. The CNG fleet consists of 459 buses and will slowly be replacing the conventional diesel-powered buses, with five added every week. The transition period is expected to be complete by the end of 2015. The buses are fueled by four CNG fueling stations that are supported by Clean Energy Fuels. The cleaner, cheaper burning natural gas is expected to cut fuel costs by up to two-thirds while reducing carbon emissions (Dallas Area Rapid Transit, 2013).

Dallas is not alone in adopting natural-gas-fueled vehicles. City and state fleets are beginning to adopt NGVs. Kansas City Area Transportation Authority (ATA) has followed suit by recently pledging to convert its fleet of 300 buses to natural gas over the next 12 years (Everly and Unglesbee, 2013). The Kansas City ATA is concerned with both the environmental and economic benefits associated with natural gas. The ATA estimates that, while the up-front cost for a natural gas bus is about \$40,000 more than a diesel-powered bus, the expected savings over the life of the vehicle are estimated at \$100,000. Some 80% of the cost of the most recent natural gas buses introduced to the Kansas City fleet were subsidized by the federal government. As of 2013, approximately 20% of transit buses in the U.S. ran on natural gas.

Trash trucks for cities may also become a growing market for natural gas fleet conversions. Most diesel-powered waste trucks get about 3 miles per gallon, and many municipal managers are looking to natural gas trucks as a means to cut costs amidst tight fiscal environments. According to researchers at the Solid Waste Association of North America, “only about 10% of U.S. refuse vehicles (including both public and private fleets) run on natural gas, but half of all new purchases are for natural gas trucks” (Vock, 2014). Waste Management and Republic Services, both private companies, are also making significant investments in natural gas vehicles and infrastructure.

State governments are also making investments in fleet conversions. Colorado Governor John Hickenlooper and Oklahoma Governor Mary Fallin began a multi-state coalition to lead in the procurement of NGVs for use in state vehicle fleets (Staple, 2012). States have the ability to become large purchasers of NGVs, as Oklahoma has already ordered 500 NGVs and began replacing existing state fleet vehicles with ones powered by CNG. Governor Fallin stated, “Converting the state’s fleet to CNG will save taxpayers millions of dollars in fuel costs.” (Piellish, 2013).

As natural gas prices continues to provide an attractive price differential, states looking to save money and promote the use of domestic fuel sources may play a vital role in expanding NGVs.

BENEFITS TO ADOPTION

The low price of natural gas has allowed NGVs fueled by CNG and LNG to make inroads into the transportation marketplace, and has allowed consumers to take advantage of the price differential. Additionally, NGV adoption provides many external benefits, including strengthening national security and reducing emissions of carbon dioxide and other harmful greenhouse gases. These negative externalities, which are not calculated into most savings and cost models, have the potential to be reduced by expanding natural gas in the transportation sector (Knittel, 2012). The following sections explore the external benefits associated with the rise in domestic natural gas production and the adoption of NGV technology.

UNITED STATES OIL CONSUMPTION

Globally, the U.S. is the largest consumer of oil, consuming 18,887 thousand barrels a day, while only producing 10,003 thousand barrels a day in 2013 (British Petroleum Company, 2014). Given that the U.S. consumption is nearly double its production, the U.S. must rely on imports. In 2013, the U.S. imported 9,792 thousand barrels a day, which was a 7.5% decrease from the previous year (British Petroleum Company, 2014).

Currently, the U.S.'s consumption is at the lowest it's been in 16 years. The U.S. Energy Information Administration (EIA) suggested that the lower demand was related to the, "weaken[ed] economy, high unemployment, growing vehicle efficiency, and high fuel prices" (Rascoe, 2013). Similarly, the EIA projects that natural gas consumption and prices will rise if the U.S. experiences economic growth and increasing resource recovery rates (U.S. Energy Information Administration, 2014a).

Although the U.S. has decreased its oil imports and consumption each year since 2010, the continued reliance on imported oil has called into question issues of national security (British Petroleum Company, 2014). The following section explores national security issues relating to reliance on foreign oil imports, and the ability of natural gas to offset some of those concerns.

NATIONAL SECURITY

National interest in energy independence is not a new phenomenon. Peak oil, the idea that the world's supply of oil will at some point reach its peak in production and competition will ensue for the remaining reserves and the price fluctuations associated with an increasing global economy are very real concerns. The Center for American Progress' *Securing America's Future* report has assigned numerical values to the cost of oil. Over the past decade the U.S. has spent \$2.3 trillion on crude oil and \$1.5 trillion on oil imports (Center for American Progress, 2009). The findings suggest that the monetary cost of reliance on oil and oil imports has widened the trade deficit, weakened the U.S. economy and more importantly allowed our political interests to be influenced by our reliance on imported oil (Center for American Progress, 2009). Similarly, a RAND Corporation report found the following:

- An abrupt and extended fall in the global oil supply and the resulting higher prices would seriously disrupt U.S. economic activity, no matter how much or how little oil the U.S. imports.
- Oil-export embargoes have been ineffective in advancing the foreign policy goals of oil exporters.
- Oil-export revenues have enhanced the ability of rogue states, such as Iran and Venezuela, to pursue policies contrary to U.S. interests.
- Terrorist attacks cost so little to perpetrate that attempting to curtail terrorist financing through measures affecting the oil market will not be effective.
- The U.S. might be able to save an amount equal to between 12 and 15% of the fiscal year 2008 U.S. defense budget if all concerns for securing oil from the Persian Gulf were to disappear (RAND Institute, 2009).

The report strengthens the argument that the cost of dependence on oil as our major fuel source places national security in jeopardy. Yet, the above findings fail to address the increasing global demand being placed on oil. Developing countries with increasing middle class populations are demanding more energy needs as they develop. Exxon Mobil predicts that the energy demand in developing nations will rise 65% in the next 30 years, with an increasing population rising from seven to nine billion, mainly in Africa and India. The increased demand will be seen in electricity generation, industrial, transportation, and residential needs (Exxon Mobil, 2013). NGVs provide an opportunity for the U.S. to mitigate the national security issues associated with dependence on oil while reducing greenhouse gas emissions.

ENVIRONMENT

Natural gas is often touted as “by far the cleanest burning” fossil fuel (U.S. Department of Energy, 2009). This clean burning fuel not only offers solutions to issues dealing with national security, but has the opportunity to aid in improving air quality. Natural gas is domestic and abundant with recent estimates suggesting that the domestic reserves can support the U.S.’s energy needs for generations. Recent domestic energy forecasts suggest that the U.S. will see a 24% increase of electricity generation needs by 2035 (Americas Natural Gas Alliance, 2012). Natural gas offers a cleaner option, to the expected increase than coal or oil for the U.S.’s electric generation energy needs. Furthermore, natural gas utilized in the transportation sector stands to drastically reduce emissions, helping the U.S. achieve stricter air quality standards.

The transportation sector accounts for up to 70% of U.S. oil consumption, and for approximately 28% of total U.S. greenhouse gas (GHG) emissions. Worldwide, transportation is responsible for over 13% of global GHG emissions (U.S. Department of Energy, 2014e). Given that natural gas vehicles emit up to 30% less harmful GHGs compared to their conventional gasoline and diesel counterparts, including carbon dioxide (CO₂), carbon monoxide (NO_x), and sulfur oxides (SO_x), NGVs offer viable solutions in curbing emissions (U.S. Department of Energy, 2013a). Overall NGVs are 30% cleaner than conventional fueled vehicles, and the American Natural Gas Alliance suggests that converting one diesel trash truck is the equivalent of taking 325 cars off the road (ANGA, n.d.). Table 5 shows emission reductions for NGVs compared with similar models of diesel vehicles.

TABLE 6: Emission Reductions of Natural Gas Vehicles Compared with Similar Models of Diesel Vehicles (percent difference)
(Source: Argonne National Laboratory, 2010)

Emissions	CNG trucks (United Parcel Service)	LNG Buses (Dallas Rapid Transit)	LNG Semi Trucks (Raleys)	LNG Refuse Trucks (Waste Mgmt)
PM (particulate matter)	-95	Not statistically significant	-96	-86
NOx (nitrogen oxides)	-49	-17	-80	-32
NMHC (non-methane hydrocarbons)	-4	-96	-59	-64
CO (carbon monoxide)	-75	-95	+263	+80

The U.S. has a unique opportunity to utilize domestically-produced natural gas to lower many GHG emissions while strengthening our national security. The fact that the transportation sector is responsible for large amounts of GHG emissions and the largest user of oil, NGV adoption in the heavy-truck and fleet vehicle sector offers a unique opportunity to mitigate national security issues while helping to curb emissions. The following policies offer proposals for expanding the NGV market.

POLICY PROPOSALS: THE HAMILTON PROJECT

The following policy proposal is directed at encouraging the use of natural gas in transportation is based on two major barriers: the lack of fueling infrastructure; and the unseen social costs associated with petroleum. They were first presented in The Hamilton Project at the Brookings Institute's, *Leveling the Playing Field for Natural Gas in Transportation*, by Christopher Knittel at Massachusetts Institute of Technology. The following is laid out in steps, providing solutions to the above mentioned barriers,

Infrastructure-Based Policies

1. Encourage home refueling by pricing natural gas for CNG vehicles at efficient rates. (State utility commissions should require local distribution companies [LDCs] to price natural gas for refueling at marginal cost, or at the cost of producing and distributing an additional unit of natural gas.)
2. Encourage local distribution companies to offer CNG stations. (State utility commissions should allow LDCs to build natural gas fueling stations and to re-coup their investments by including them in their rate base.)

3. Establish an industry consortium to investigate and coordinate on LNG refueling infrastructure. (DOE could create such a consortium to establish so-called blue corridors networks of refueling stations along widely used routes.)

Vehicle and Fuel Based Policies

1. Include methanol in the Renewable Fuel Standard. (Congress should expand the Energy Independence and Security Act [EISA] by expanding the scope of fuels that fit their criteria of moving the U.S. toward greater energy independence and security.)
2. Mandate a significant share of vehicles manufactured to be able to burn gasoline, ethanol, and methanol. (Congress should take action to require that vehicles must be “tri-fuel,” introduced in stages that will provide reason to invest in refueling infrastructure.)
3. Provide subsidies for natural gas vehicles commensurate with the reduction in external costs associated with their use. (CNGs should be on-par with electric vehicle subsidies and tax incentives.)
4. Streamline the retrofitting certification process for gasoline vehicle conversion to CNG. (The Environmental Protection Agency should provide streamlined certification process that is not unduly expensive) (Knittel, 2012).

Christopher Knittel’s policy proposals are by no means exhaustive, but they serve to highlight the many aspects involved in promoting natural gas vehicles adoption. Both federal subsidies and private financing programs exist to help reduce the up-front cost of purchasing natural gas trucks and bus fleets. Many companies like UPS and municipalities like Kansas City and Dallas are taking advantage of such programs.

POLICY PROPOSALS: NATIONAL ENERGY POLICY INSTITUTE

The National Energy Policy Institute’s *What Set of Conditions Would Make the Business Case to Convert Heavy Trucks to Natural Gas?—A Case Study* based its policy suggestions off the findings of the Lynden Inc. case study. The following are policy options to support the adoption of natural gas in the heavy truck market.

1. Weight Exclusion. A weight credit or “allowance” for the additional weight of natural gas fuel tanks would eliminate the concern and financial impact of a diminished payload as trucks are limited to a certain Gross Vehicle Weight and any additional weight reduces payload they can carry.
2. Eliminate the Federal Excise Tax (FET) for Natural Gas Heavy Trucks. (The Federal Excise Tax accounts for roughly ten percent of the incremental cost of a heavy-duty natural gas truck; this would reduce the high capital cost of the truck.)
3. Ensure a minimum \$1.25-\$1.50 price differential between diesel and natural gas. (This would serve to reduce concern and risk associated with a large capital investment in natural gas vehicles followed by a narrowing in the price differential.)
4. Tax Credits and Grants for Infrastructure and Vehicles. (A tax credit for the additional cost of a natural gas tractor reduces the additional cost of associated risk of investing in natural gas.)
5. Mitigate Barriers Related to Maintenance Shop Upgrades. (A tax credit for upgrades to natural gas maintenance garages would help mitigate high capital cost to upgrade.)

6. Change the Federal Excise Tax on LNG to a DGE (per Btu) basis. (LNG and diesel are taxed on a per gallon basis. LNG contains less energy per gallon this is equivalent to a tax penalty for LNG.)
7. Access to Capital (Low-interest loans would help mitigate high incremental costs and costs in securing private loans.) (Deal, 2012).

In many ways, governmental entities are already involved in the promotion of NGVs and the use of natural gas in the transportation sector. The following sections look at the current governing policies and incentives relating to NGVs.

GOVERNING POLICIES

FEDERAL

At the federal level, incentives for natural gas vehicles (NGVs) come in the form of tax incentives and grants. Both aim to promote the adoption and use of NGVs, while aiding in the reduction of America's dependence on foreign oil and the lowering of urban air pollution and greenhouse gases. Several tax incentives were included in the Energy Policy Act of 2005 and extended with the Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010, and the American Taxpayer Relief Act of 2012:

- *Income Tax Credits of Alternative Fuel Infrastructure:* income tax credit equal to 30 percent of the cost of installing new natural gas-refueling equipment. The credit is worth up to a maximum of \$30,000 in the case of business property and \$1,000 for home refueling appliances. This incentive is intended to expand the availability of natural gas-refueling stations, increase use of natural gas as a motor vehicle fuel, and reduce demand for petroleum motor fuels.
- *Excise Tax Credit to the Seller of CNG or LNG:* provides an incentive for compressed natural gas (CNG) and liquefied natural gas (LNG) when used as a “motor vehicle” fuel (including use in some non-road vehicles). The 50-cent incentive is provided to businesses, individuals, and tax-exempt entities that sell or, in some cases, use the fuel. The general rule is that the credit goes to the seller in the case of retail transactions. If the CNG or LNG, however, is dispensed using a private fueling station, the credit may go to the user of the fuel. This is explained below in greater detail. For businesses and tax-exempt entities (e.g., federal, state and local governments), the credit must first be taken as an excise tax offset against taxes otherwise owed on alternative fuel they use or sell, and then it may be taken as a refundable credit.
- *Income Tax Credits for Alternative Fuel Vehicles:* provides an income tax credit for businesses and individuals that acquire alternative fuel motor vehicles, including natural gas vehicles (NGVs). The potential value of the tax credit varies depending on the size of the vehicle, the incremental cost of the vehicle, and the emissions performance of the vehicle. In order to qualify for the incentive, a person or business must be a taxpayer, be the original or first user of the vehicle, and the vehicle must be a dedicated NGV. Conversions also qualify as long as the vehicle was not previously an NGV and as long as the other requirements discussed below are met. The vehicle must be one that has been primarily manufactured for use on “public streets, roads, and highways” (NGV America, 2012).

Current grants include:

- *Congestion Mitigation and Air Quality Improvement (CMAQ) Program:* provides efforts to attain the National Ambient Air Quality Standards (NAAQS), governed by the Clean Air Act. The CMAQ program was implemented to support surface transportation projects and other related efforts that contribute air quality improvements and provide congestion relief. The CMAQ program has provided nearly \$30 billion for just about 29,000 transportation/environmental projects to state DOTs, metropolitan planning

organizations, and other sponsors across the country (U.S. Department of Transportation, 2014).

- *Federal Transit Authority (FTA) Grants*: provides grants to help fund local and regional public transit systems. FTA helps communities support public transportation by issuing grants to eligible recipients for planning, vehicle purchases, facility construction, and operations. Eligible recipients must be public bodies such as states, cities, towns, regional governments, and transit authorities with the legal authority to receive and dispense federal funds (NGV America, 2014a).
- *Moving Ahead for Progress in the 21st Century Act (MAP-21)*: provides over \$105 billion of funding for surface transportation programs for FY 2013 and FY 2014. MAP-21 will extend various programs that have been a major source of financial assistance to transit systems wanting to upgrade their aging fleets with new natural gas vehicles (U.S. Government Information, 2012).

The fuel and infrastructure incentives identified above were set to expire at the end of 2012, but the Fiscal Cliff bill passed on January 1, 2013 extended them until the end of 2013. At the end of 2013, extensions were not awarded and about 60 tax incentives, including those for NGVs, expired (NGV America, 2014b). Due to the failure to extend these incentives, the prices for natural gas are expected to rise at the fuel pump. Many CNG stations across the U.S. were using a 50-cent tax credit per diesel-gallon-equivalent (DGE) to cover their costs. Natural gas producer Apache, providing CNG to several stations in Texas (also in Oklahoma, New Mexico, Louisiana), was passing the credit along to consumers. Due to its ability to keep prices low, Apache experienced an 88% increase in CNG sales at its stations. But expired tax incentives will force many fueling stations to raise their prices.

NGV America is a national organization that focuses on the advancement of natural gas and biomethane. It represents private companies, environmental groups and governmental organizations that promote natural gas as a transportation fuel. There are several federal legislative issues that the organization is focused on for 2014. First are solutions to address the expired tax incentives. NGV America supports legislation that would either include natural gas and NGV tax incentives in another extender bill, or would incorporate them into a more comprehensive piece of tax reform legislation. The latter option is likely more difficult to pass.

Second, the group is focused on balancing the LNG tax inequity. LNG competes directly with diesel for long-haul trucking. Currently, the federal excise tax on each fuel option is the same, at 24.3 cents per gallon. As previously highlighted, however, LNG does not have the same energy per gallon as diesel. NGV America argues that basing tax on volume rather than energy content causes LNG to be taxed at 170% the rate of diesel, and that this inequity causes disinvestment in natural gas infrastructure and NGVs. Through two proposed bills, one in the House of Representatives (H.R. 2202) and one in the Senate (S. 1103), the organization seeks to amend the current taxing structure to remove inequity.

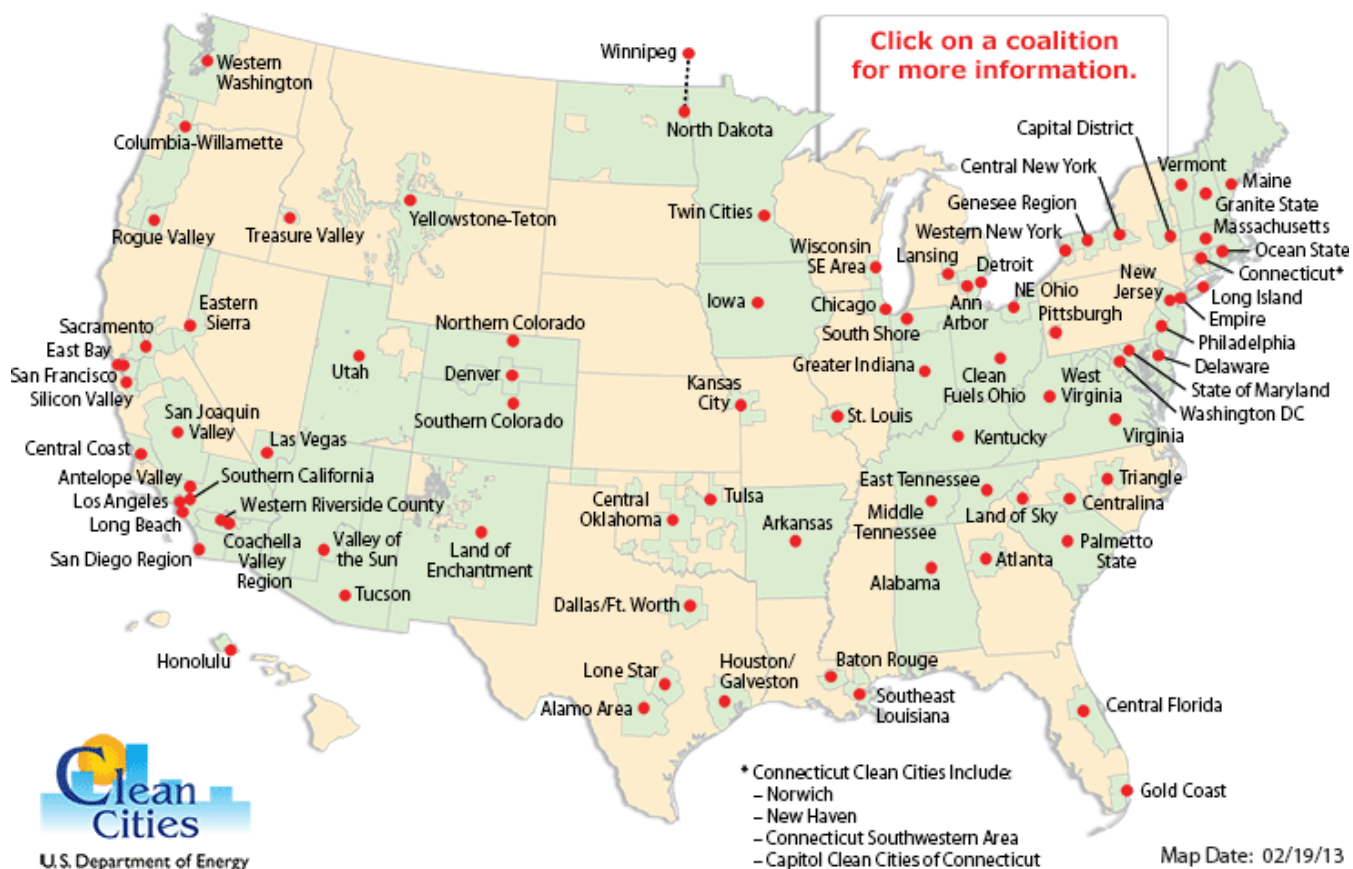
Third, NGV America is pushing for the elimination of the Federal Highway Excise Tax (FET) on heavy trucks and tractors. The current system imposes a 12% tax on these vehicles. It is argued that, due to the higher costs of natural gas trucks, the FET places a much greater tax burden on fleets with natural gas vehicles. Finally, NGV America is focused on weight limits for natural

gas trucks. As the tank and storage systems for natural gas trucks are heavier than that of diesel, these trucks are unable to carry as much freight on federal highways due to weight limits. The organization estimates a revenue loss of up to 2-3% due to this issue. Through a bill in the House (H.R. 3940), NGV America is seeking to create a weight exemption for heavy-duty natural gas trucks. States like Ohio and Indiana have already passed statewide legislation allowing for weight exemptions on intrastate roads (NGV America, 2014c).

CLEAN CITIES PROGRAM

With the wide array of incentives and grants, coordination on the state and local level is implemented by the Clean Cities Program through the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy Vehicle Technologies Program. Clean Cities' primary goal is to reduce petroleum use in the U.S. by 2.5 billion gallons per year by 2020. To achieve this goal, Clean Cities employs three strategies: replacing petroleum with alternative and renewable fuels; reducing petroleum consumption through smarter driving practices and fuel economy improvements; and eliminating petroleum use through idle reduction and other fuel-saving technologies and practices (U.S. Department of Energy, 2014a). Figure 11 highlights the current coalitions of stakeholders in the public and private sectors in the U.S.

FIGURE 11: Clean Cities Coalition Locations
(Source: U.S. Department of Energy, 2014b)



Since 1993, Clean Cities Coalitions have funded more than 500 transportation projects nationwide through a competitive application process. Clean Cities has distributed \$377 million in project awards, and by forming strategic coalitions with stakeholders in the private and public sectors, Clean Cities has dispersed an additional \$740 million, saving more than \$4.5 Billion gallons of petroleum (U.S. Department of Energy, 2014c). The majority of the alternative fuels and vehicles (75.0%) savings has been fueled by natural gas (at 55.9%) (U.S. Department of Energy, 2014d).

Many states have introduced policies to promote the use of natural gas vehicles. Clean Cities is instrumental in forming alliances with private and public entities and offer guidance to implementation. The following section details current policy initiatives in several states that focus directly on natural gas development, or have the likelihood to directly affect the natural gas and NGV industry development.

STATE FOCUS

Oregon

The Oregon Clean Fuels Program, part of the Oregon Department of Environmental Quality (DEQ), was established by the state legislature in 2009 and aims to reduce greenhouse gas emissions of transportation in the state. According to the DEQ, one third of the emissions in Oregon are the result of transportation fuels. The Clean Fuels Program has been seeking to implement low-carbon fuels standards for the state that entail reducing the carbon in diesel fuel by 10% by 2020 (Oregon Department of Environmental Quality, 2014). According to the Oregon Trucking Associations, the standards would cost the trucking industry approximately \$7 billion per year in extra fuel costs and force job loss (Transport Topics, 2013a).

Senate Bill 488, introduced in 2013, aimed to extend the sunset date of the Clean Fuels Program to beyond 2015, but was not passed (Transport Topics, 2013a). Legislative action was again taken in 2014 to further implement the policy goals of the program. Should stricter low-carbon standards be enforced in Oregon, the focus may turn to natural gas as a means to save money and meet the low-carbon standards. As investment in NGVs and alternative fuels is highlighted as a main focus of the Statewide Transportation Strategy for Oregon through 2050, it is likely that policy changes directly affecting fuel costs for the trucking industry will put greater emphasis on natural gas as a cost-effective and environmentally beneficial solution.

Florida

The 2013 legislative action in Florida also produced policies intended to expand the use of natural gas vehicles. HB 579 signed into law the Florida Natural Gas Vehicle Act, which set forth several incentives (Transport Topics, 2013c). First, the bill eliminated state taxes on both compressed-natural-gas (CNG) and liquefied-natural-gas (LNG) fuels for five years, until 2018. After 2018, natural gas will be taxed at 21 cents per diesel-gallon-equivalent (DGE) as opposed

to the 31 cents for diesel. Second, the legislation eliminated the decal and license programs for natural gas fuel. Third, the bill called for \$6 million annually to be given as rebate funds for five years, with 60% going to private fleets and 40% of the funding dedicated to government fleets. The bill allowed for funding of up to \$25,000 per vehicle to help carriers purchase NGVs. Eligibility is capped at \$250,000 (Arroyo, 2013).

Finally, the bill included excise tax exemptions and exemptions aimed at stimulating natural gas infrastructure development. Eric Criss, chairman of the Florida Natural Gas Coalition (representing 15 companies), noted that policies set forth in HB 579 were vital to environmental impact and national security. The Coalition released an Economic Impact Study which estimated NGV incentives would produce 10,000 jobs, \$300 million in wages and \$1 billion in economic output over a 20-year period. It is clear that Florida is focused on policies geared toward making NGVs an integral piece of their transportation industry (Arroyo, 2013).

Wyoming

In Wyoming, the development of natural gas infrastructure has become a key element of the state energy policy. In mid-2014, the results of a commissioned report were announced by Governor Matt Mead. Funded by the state government and private energy companies, the report by an outside energy consulting company speaks to the benefits gained from public-private investment in LNG production and distribution, particularly to heavy industrial users like on-road semi-trailers. It reported that an investment of \$400 million to, “develop a liquefied natural gas system primarily serving the state’s coal-producing Powder River Basin region could result in \$166 million annual fuel savings versus continued use of diesel fuel” (Fuetsch, 2014). Wyoming is currently a top-producing state of natural gas and the leader in coal production. Applying LNG to new sectors of the state economy, like heavy-duty trucks, opens up the possibility for significant cost savings as well as job creation. The creators of the report predict that LNG will be readily available for new applications in Wyoming over the next several years.

Wyoming is an interesting example of state policy towards natural gas. As a leading producer of coal, the state economy is heavily reliant on the industry. While many other states are incorporating natural gas infrastructure development to reduce their reliance on energy sources like coal power, Wyoming must take a different approach. Through adjusting its current distribution processes for a major sector of their economy, the state may be able to take advantage of natural gas technologies for the mine haul trucks, drilling rigs, and trains that provide both economic and environmental benefit.

New York

In New York, LNG facilities have been banned in the state since 1973, when an explosion at an LNG storage facility in Staten Island killed 40 workers. In 2013, state legislators proposed new regulations that would allow for new fueling stations and storage facilities to be built. These actions signify a significant shift in policy interest towards LNG. Currently, the transportation of LNG is only allowed on federal highways and limited local roads. The New York State Department of Environmental Conservation (DEC) drafted regulation in late 2013 that followed legislators’ proposals to construct new fueling stations and storage facilities. The DEC claims that if permitting is allowed, first permits would go to smaller facilities that supply LNG to

heavy-duty trucks and fleet vehicles. It also estimates that approximately 21 new fueling stations would be built within the first five years (Associated Press, 2013a).

These new policy proposals could mean a significant opportunity for growth of natural gas adoption in New York State, but it does not come without concern. Environmental groups like New Yorkers Against Fracking fear that these regulations open the door for the development of shale gas drilling infrastructure. A state-wide moratorium on fracking was put in place in 2010 and environmental impact studies of fracking continue to be conducted. It is unclear whether a greater presence of LNG would in fact lead to a loosening of fracking bans, but groups like the New York Public Interest Research Group (NYPIRG) believe the DEC's proposals would allow more widespread transportation of LNG fuel and would not limit the size of LNG facilities built. Clean Energy Fuels Corp. already has plans for two fueling stations in New York, pending the approval of new permits (Associated Press, 2013b).

California

California has the toughest limitations on greenhouse gas emissions in the U.S. Existing cap-and-trade programs in the state focus on emissions from power generators, refineries and industrial plants, but new policy proposals would impose a carbon tax directly on drivers. This new policy calls for a 15-cent-tax per gallon on regular gasoline, rising to 24 cents by 2020 (Marois, 2014). It is part of state-wide efforts to reduce carbon emissions by 15% in that same time period. Revenue from the new carbon tax, estimated to be \$3.6 billion in its first year, would go towards an earned-income tax credit for families who earn less than \$75,000 per year and investments in public transit. Regular gasoline prices in California are the second-highest in the U.S. (Marois, 2014). If the carbon tax policy proposals are adopted, focus for industry and consumers may shift towards a greater use of natural gas, as it offers both lower prices and lowered carbon emissions.

While the carbon tax proposals may effectively bolster natural gas adoption in the state, greater emphasis on the use of electric- and hydrogen-powered trucks could negatively affect natural gas growth and NGV adoption. In May of 2014, the California Air Resources Board (CARB) approved a plan that calls directly on the trucking industry to transition its vehicles from diesel power to electric and hydrogen power by 2050. The overall goal is to achieve near-zero emissions from trucks (Miller, 2014). The plan states that, for freight, new mandates mean, "moving goods more efficiently and with zero- or near-zero emissions: providing acceptable velocity and expanded system capacity: and optimizing movement of freight between modes, while integrating with the national and international freight transportation system" (Miller, 2014). Representatives from the American Trucking Associations (ATA) and the California Trucking Association are skeptical that the heavy-duty trucking industry will be able to meet a 2050 timeline, as technology for zero-emissions Class 7 or 8 trucks simply does not yet exist. The significant shift in policy goals, set forth by CARB, certainly take emphasis away from further investment in natural gas for trucks and fleet vehicles. It is not yet clear how these new mandates will shape the trucking industry, but it has important and significant implications for natural gas infrastructure and NGV investment in the future.

Each of the policy initiatives highlighted here have the potential to shape NGV adoption across the U.S. But it is important to take a closer look at what is directly affecting natural gas investment in Texas. The following sections provide an in-depth look into Texas legislation, and current incentives, both public and private, for promoting the adoption of natural gas vehicles in the state.

TEXAS

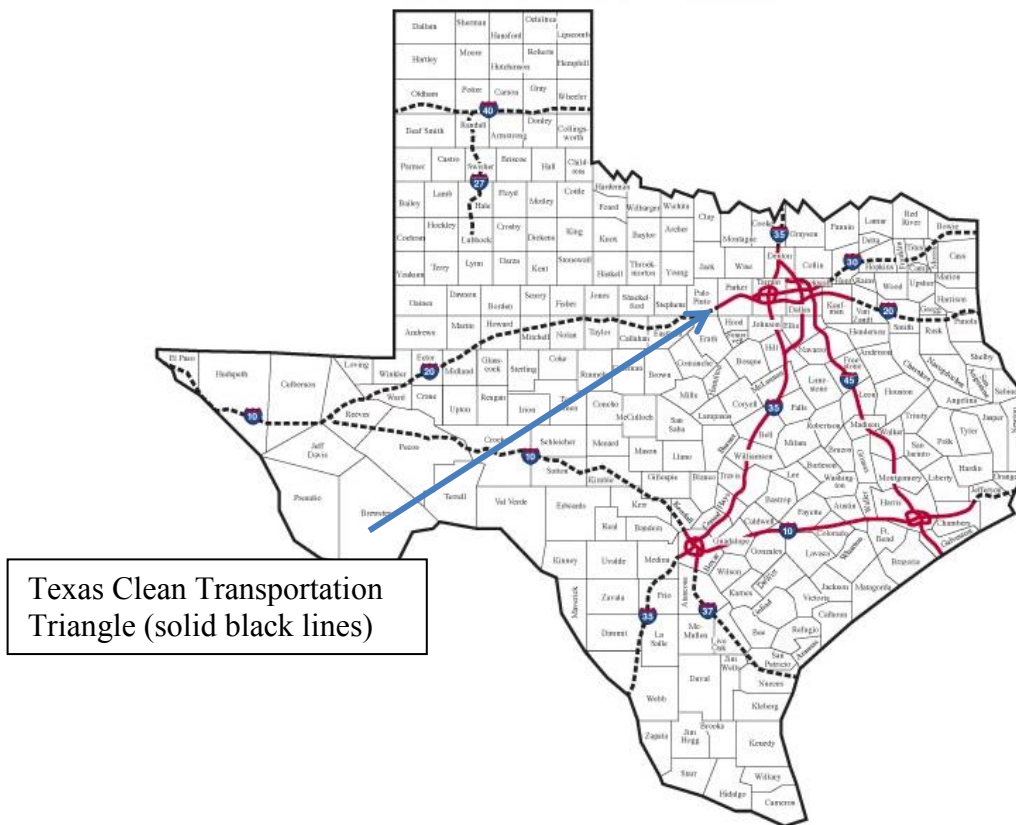
Current Texas policies regulating and encouraging the use of natural gas vehicles have come from a need for the state to meet the minimal guidelines established by the Federal Clean Air Act (42 U.S.C. section 7407). The Texas Emissions Reduction Plan (TERP) was established by the 77th Texas Legislature in 2001 with the passage of Senate Bill 5. The plan has a number of incentives to encourage investment in alternative fuel vehicles (AFVs), including natural gas vehicles and money dedicated to infrastructure development to fuel those vehicles. The plan has been instrumental in guiding Texas policies toward the adoption of natural gas. The goals of the Texas Emissions Reduction Plan include:

- Assure that the air in this state is safe to breathe and meets minimum federal standards established under the Federal Clean Air Act (42 U.S.C. section 7407);
- Develop multi-pollutant approaches to solving the state's environmental problems; and
- Adequately fund research and development that will make the state a leader in new technologies that can solve its environmental problems while creating new business and industry in the state (Texas Commission of Environmental Quality, 2014).

Texas Clean Transportation Triangle

Texas enacted legislation with the passage of Senate Bill 20 in the 82nd legislative session leading to the development of the Texas Clean Transportation Triangle (TCTT). The bill allocates 20% of allocated TERP funds, specifically for the conversion of heavy-duty fleet vehicles to run on natural gas and the infrastructure to support the conversion and utilization of NGVs. The funding is further broken down with 80% going toward heavy-duty NGV rebates, and the other 20% of the funding specified for refueling infrastructure (Texas House Research Organization, 2011). The Texas Clean Transportation Triangle brought together both public and private interests, with the goal of improving Texas's air quality. Figure 13 shows a map of the TCTT. The corridor, outlined by the solid black lines, connects Dallas/Ft. Worth, Austin, Houston, and San Antonio utilizing the I-45, I-35, and I-10 routes.

FIGURE 12: Texas Clean Transportation Triangle
(Source: Texas Commission on Environmental Quality, 2013)



Benefits of the Texas Clean Transportation Triangle

- More than \$135 million in direct investment in the Texas economy will support nearly 1,000 clean-fuel technology jobs.
- Heavy-duty fleet operators report 30-40% cost savings for natural gas fleet operations compared to diesel.
- More than \$30 million in fuel costs savings, using lower cost Texas-produced natural gas in place of more expensive diesel fuel, can be invested back into Texas businesses, jobs and the Texas economy.
- Reduced reliance on foreign energy, by displacing more than 41 million gallons of petroleum-diesel fuel use with more than 6 billion cubic feet (bcf) of Texas produced natural gas. (Source: Gladstein, Neandross & Associates)
- Replacing heavy-duty diesel trucks, the most significant contributors to urban air-quality problems, with clean-burning, low-emission NGVs offers one of the best potential strategies to improve Texas air quality and meet air quality standards.
- Emission benefits from the implementation of the TCTT are the equivalent of taking more than 175,000 cars off Texas highways in the state's most populated areas (Texas Natural Gas Now, 2012).

Further legislation relating to NGVs and refueling infrastructure is Senate Bill 385 during the 82nd legislative session that created the Alternative Fueling Facilities Program to provide incentives to build refueling stations for alternative fuel fleets. The program overseen by the Texas Commission of Environmental Quality offers reimbursements up to \$500,000 to incentivize the construction of the fuel stations to encourage the use of natural gas vehicles (Texas Legislature Online, 2012). In addition, House Bill 3399 incentivized large fleet owners to replace diesel-powered vehicles with alternative fuel vehicles. The bill authorized \$5.7 million for the Texas Commission of Environmental Quality to encourage the replacement of high pollutant diesel trucks.

Texas Incentives

The majority of the incentives are under the direction of the Texas Commission of Environmental Quality (TCEQ), which regulates the state's natural resources and public health, and promotes sustainable economic development. Other entities, including the General Land Office and the Texas Railroad Commission also administer incentives. The following is a list of available incentives in Texas.

- *Alternative Fueling Infrastructure Grants*: part of the Texas Emissions Reduction Plan (TERP), provides grants for 50% of eligible costs, up to \$500,000, to construct, reconstruct, or acquire a facility to store, compress, or dispense alternative fuels in Texas air quality nonattainment areas (Texas Legislature Online, Health and Safety Code 386 and 394).
- *Natural Gas Vehicle (NGV) and Fueling Infrastructure Grants*: part of TERP, which provides grants to replace existing medium- and heavy-duty vehicles with new, converted, or repowered NGVs. Qualifying vehicles must be on-road vehicles with a gross vehicle weight rating of more than 8,500 pounds and certified to current federal emissions standards (Texas Commission on Environmental Quality, 2014a).
- *Clean Vehicle and Infrastructure Grants*: part of TERP, provides grants for various types of clean air projects to improve air quality in the state's nonattainment areas. Eligible projects include those that involve replacement, retrofit, repower, or lease or purchase of new heavy-duty vehicles; alternative fuel dispensing infrastructure; idle reduction and electrification infrastructure; and alternative fuel use (Texas Commission on Environmental Quality, 2014b).
- *Clean Fleet Grants*: part of TERP, which encourages owners of fleets containing diesel vehicles to permanently remove the vehicles from the road and replace them with alternative fuel vehicles (AFVs) or hybrid electric vehicles (HEVs). Grants are available to fleets to offset the incremental cost of such replacement projects. An entity that operates a fleet of at least 75 vehicles, including at least 20 diesel-powered vehicles, and that commits to placing 20 or more qualifying vehicles in service for use entirely in Texas during a given calendar year may be eligible. Qualifying AFV or HEV replacements must reduce emissions of nitrogen oxides or other pollutants by at least 25% as compared to baseline levels and must replace vehicles that meet operational and fuel usage requirements (Texas Commission on Environmental Quality, 2014c).
- *Natural Gas Fuel Rates and Alternative Fuel Promotion*: the Texas General Land Office (GLO) makes competitively priced natural gas available to school districts and other state and local public entities for use in natural gas vehicles. The GLO has also

established an alternative fuels program to aggressively promote the use of alternative energy sources, especially for those fuels abundant in Texas. The GLO alternative fuels program serves as a liaison between government and industry (Texas General Land Office, 2014).

- *Alternative Fuel Vehicle Replacement Grants*: the Texas Railroad Commission offers grants to buyers who wish to replace aging medium- or heavy-duty diesel school bus or delivery vehicles with qualified propane or natural gas vehicles that meet or exceed current U.S. Environmental Protection Agency (EPA) emissions standards (Texas Railroad Commission, 2014).

There are more incentives administered by private companies and utilities. Clean Energy Fuels Corp. offers long-term fuel prices and alternative fuel vehicle financing. The Texas Gas Service offers cash incentives for the conversion or purchase of NGVs. Center Point Energy offers feasibility studies for natural gas fueling stations (U.S. Department of Energy, 2013a).

Local

- *Alternative Fuel Vehicle (AFV) Grants - Houston - Galveston, TX*: The Houston-Galveston Area Council provides Congestion Mitigation and Air Quality (CMAQ) program grants through the Houston-Galveston Clean Cities Coalition and Clean Vehicles Program for up to 75% of the cost of clean vehicle or equipment replacement, AFV conversions and repowers, vehicle or equipment retrofits, and anti-idling technologies. Funding is also available for up to 75% of eligible equipment costs to establish alternative fueling infrastructure. This grant is for public and private entities in the eight-county Houston-Galveston-Brazoria nonattainment area (U.S. Department of Energy, 2013d.).
- *Clean School Bus Program - North Central TX*: The North Central Texas Council of Governments administers the North Central Texas Clean School Bus Program, which is a fuel- and technology-neutral program. The Clean School Bus Program serves as a clearinghouse for information on technology, legislation, best practices for school bus operators, and clean school bus funding opportunities. The Clean School Bus Program aims to reduce emissions from school bus fleets by encouraging and assisting in the expedited purchase of clean school buses as well as the adoption and enforcement of idle reduction policies (U.S. Department of Energy, 2013d.).

While no City of Austin incentives currently exist, the Austin City Council recently took steps to support policy related to fracking. In 2014, the City of Austin enacted a resolution that supported Representative Matt Cartwright's federal legislation titled "The Cleaner Act" (H.R. 2825) (Ross, 2014). The bill calls for the closing of fracking loopholes that exempt fracking operations from key provisions of federal hazardous waste law. The council resolution acknowledges some of the harmful environmental impacts of fracking (i.e., toxic wastewater, groundwater contamination, and improper storage) and takes a clear stand in terms of policy (Congressional Research Service, 2014).

BARRIERS AND OPPORTUNITIES

Although there are many benefits to natural gas vehicles, there are still barriers in the marketplace that must be addressed in order for NGVs to fully realize their place in the U.S. transportation sector. Issues affecting NGV adoption include public perception, environmental and community impact concerns over fracking, and the changing political landscape. These factors affecting NGV adoption are discussed below.

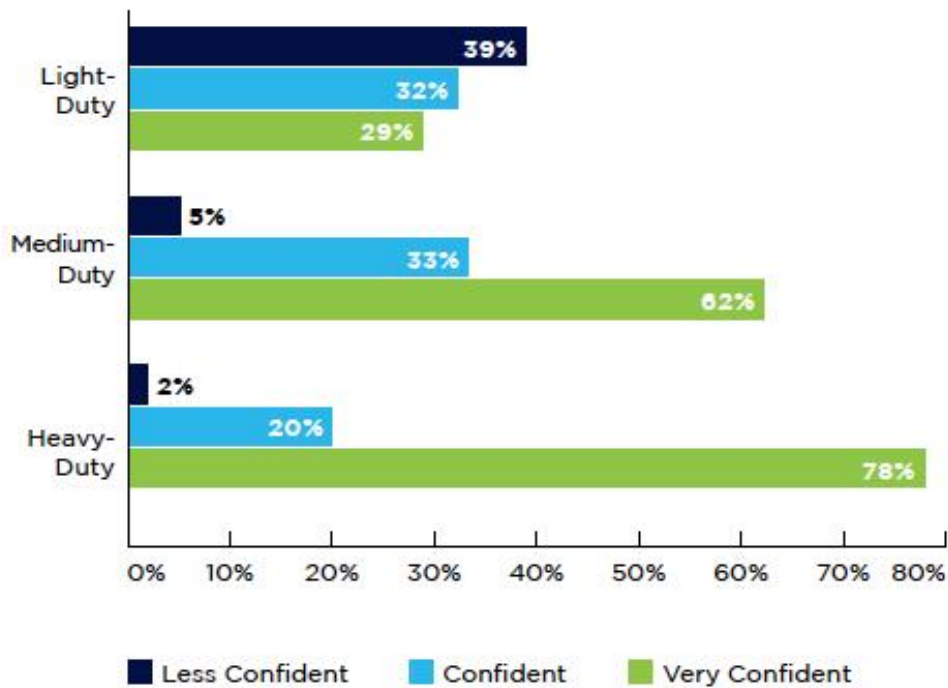
PUBLIC PERCEPTION

One of the largest barriers for NGVs is public perception. Mainly, what is this new technology, how does it work, and will it fulfill my transportation needs? As the largest growth in NGVs is expected to come in long-haul trucks and fleet vehicles, the perception of adopters and decision makers is key.

In 2012, the American Clean Skies Foundation surveyed industry stakeholders, both public and private on the perceived barriers facing the NGV market. The survey illustrates both barriers and opportunities which are often closely tied. The survey began by discussing confidence in the NGV market. Figure 14 below breaks down the responses by confidence ratings of each market segment of NGVs: light-duty, medium-duty, and heavy-duty. Some 98% of respondents reported either “Very Confident” or “Confident” that the heavy-duty market would grow in the coming year. This in itself speaks to the opportunities in the NGV market segments, especially in heavy- and medium-duty, which are able to fully capitalize on the price differential between conventional diesel and CNG or LNG, as evident in the Lynden Inc. case study. Furthermore, by 2020, about 60% of respondents thought that the price of NGVs would be half of today’s prices (American Clean Skies Foundation, 2012).

FIGURE 13: NGV Growth Confidence
(Source: American Clean Skies Foundation, 2012)

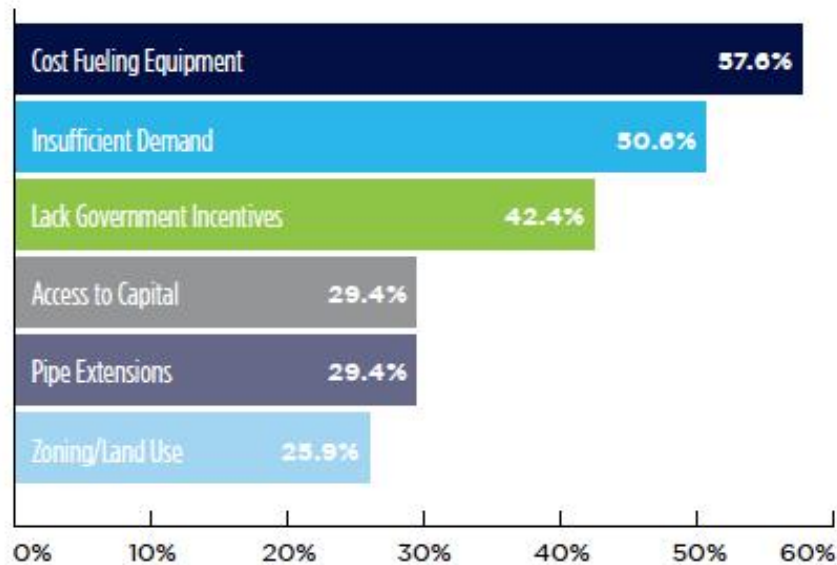
How confident are you that each of the below
NGV market segments will grow in the coming year?



The survey then addresses one of the major concerns of fueling infrastructure costs. Figure 15 below shows that almost 58% of respondents reported that the cost of fueling equipment was the biggest barrier, followed closely by insufficient demand, and lack of government incentives. Access to capital and pipe extensions both were reporting around 30% and zoning and land use the least significant impediment at about 26% (American Clean Skies Foundation, 2012).

FIGURE 14: NGV fueling station impediments
(Source: American Clean Skies Foundation, 2012)

Which is a significant impediment to building new fueling stations?
Respondents were asked to check as many as apply.



The survey concludes by asking, “Which of the following do you see as the most important priority for government policy in 2013?” Fueling incentives was the reported highest priority, with 47%, followed by vehicle incentives at 26%. Government purchasing was reported at 12%, followed by LNG excise tax at 8% and government research and development at 6% (American Clean Skies Foundation, 2012).

While this survey is by no means all inclusive, it highlights many important aspects of major opportunities and barriers. Most importantly it demonstrates that industry stakeholders see NGVs as an opportunity for growth in the years to come. The expected growth in the industry addresses the issue of public perception of NGV technology. The acceptance and belief that NGVs can become a large-scale reality suggests that understanding of the technology, feasibility of implementation, and natural gas prices are coming together making NGVs an attractive transport option.

ENVIRONMENTAL CONCERNS

Another major adoption factor for the NGV market is the continued supply of cheap natural gas. It is important to note that focusing solely on the emissions-reduction benefits of natural gas vehicles does not comprise a comprehensive assessment of the environmental impacts of natural gas, from both its extraction and production. Hydraulic fracturing continues to be a controversial issue in the U.S., particularly given its prevalence throughout many states.

Fracking to access natural gas deposits has recently come under increased public scrutiny sparked by public outcry over environmental issues.

Over the past few years, there has been an increasingly vocal reaction to the environmental impacts of fracking, primarily focused on water contamination issues. The increase in scrutiny of the process is evident in newspapers, magazine articles, and documentary films which highlight the dangers associated with fracking. Such is particularly true in western New York State on the edges of the Marcellus Shale Play, where public pushback against natural gas producers has resulted in the state legislature extending a moratorium on fracking. The decision extended the moratorium put in place in 2010 through 2015, so that further studies can evaluate the impacts of fracking on the environment (Reuters, 2013a). While the environmental impacts of fracking continue to be understood through research, methane gas leakage and water pollution are frequently cited in arguments against the expansion of fracking and production of both oil and natural gas.

A 2013 report by the Environment America Research and Policy Center highlights some of the most significant and harmful environmental impacts of fracking in the U.S. According to the report, in 2012, fracking wells produced 280 billion gallons of waste water, often containing toxic, cancer-causing chemicals. Companies engaging in fracking do provide sealed and protected storage for much of the wastewater produced during fracking, but numerous instances of groundwater and drinking water contamination have occurred in states like New Mexico. The significant volume of water that fracking requires also depletes finite water resources (Ridlington and Rumpler, 2013). These findings have raised concerns not only about the environmental impact of fracking, but also the public health implications.

The leakage of methane gas in multiple stages of extraction and processing of natural gas is another major environmental issue that must be considered. As a greenhouse gas, methane is considered to have 20 times the global warming effect of carbon dioxide. Recent research conducted jointly by Purdue and Cornell universities found that methane emissions directly above active drilling sites were 100 to 1,000 times greater than estimates made at the inventory stage (Baker, 2014). Methane has also been found to leak during the production of natural gas, as well as the refueling process.

Many states are attempting to address public concerns over fracking and the chemicals that are used in the process. As of May 2012, 22 states had fracking fluid disclosure requirements, with an additional seven introducing new requirements, to publically disclose chemicals used in the process (Pless, 2012). This information is important for local communities in their efforts to monitor their local environmental concerns.

Environmental concerns, while important, may lead to increasing taxes, fees, and other mechanisms that may hurt the natural gas industry. As stable natural gas prices are tantamount to the adoption of NGVs, it is increasingly important to have conclusive studies relating to the impacts on the environment so that responsible drilling can be enforced and informed regulatory decisions can be made.

SOCIAL IMPACTS: PENNSYLVANIA CASE STUDY

Hydraulic fracturing for oil and natural gas has been most prevalent in states like Texas, North Dakota, and Pennsylvania. When discussion falls on the negative impacts of fracking in these states, most focus is on the harm it can cause to the environment. But equally significant are the community and social impacts of fracking – from the issues caused by the influx of workers to the increased danger associated with an increased frequency of large trucks on rural roads. One organization conducted an assessment of the social impacts of fracking in Pennsylvania, a state containing part of one of the largest shale plays in the U.S.—the Marcellus play. In 2005, the state had only eight drilling wells, but by 2011 there were 1,972. Almost all of the new wells were created in rural counties (Food and Water Watch, 2013).

The September 2013 study was conducted by Food and Water Watch, a non-profit policy organization whose focus is on ensuring access to safe food and water, while protecting vital natural resources and environmental quality in the U.S. The report is a long-term analysis of county-level data from the 35 rural counties in Pennsylvania. Of those 35 counties, 12 had experienced no fracking. Ten years-worth of data was compared in two periods of time, 2000 to 2005, which was prior to the commercialization of fracking in the state, and then 2005 to 2010, a post-fracking period. Analysis was also conducted on the eight most-heavily-fracked counties. The study focused data from heavy-truck traffic accidents, civic disturbances, and public health cases. Civic disturbances were limited to disorderly conduct arrests, and public health cases limited to reported cases of sexually transmitted infections (STI) (Food and Water Watch, 2013). The analysis looked at year-to-year changes in the data.

The study found increased instances of heavy-truck crashes in the most-heavily-fracked counties. While trends nationally have generally declined since 2005, the trend was significantly slowed in counties where fracking was occurring, and the most-heavily-fracked counties experienced an increase in the number of heavy-truck accidents. Heavily-fracked counties saw an average yearly increase of 9%, while crashes in counties without fracking declined at an average rate of 3% (Food and Water Watch, 2013). Along with higher instances of heavy truck crashes, the increased congestion caused by the higher frequency of trucks has become a significant issue for rural communities, slowing the response time of emergency vehicles, lengthening travel times, and adding significant wear and tear to roads not built to handle the heavy weight of fracking trucks. In addition, some truck crashes have led to spills of toxic wastewater onto rural roadways and contaminating surface water.

The study also found that the higher numbers of transient workers in rural communities, mainly men, have led to higher instances of disorderly conduct arrests in fracked counties compared to counties without fracking. In heavily-fracked counties, arrests rose 17.1% between the pre- and post-fracking time periods. In unfracked counties, arrests rose by 12.7%. From 2005 to 2010, the average annual increase in arrests in heavily-fracked counties was 6.9%, a reversal of declining averages before fracking (Food and Water Watch, 2013). Compared to counties without fracking, this increase was more than three times faster.

Finally, the study's results found an association with fracking growth and the transmission rates for STIs. In heavily-fracked counties, during the post-fracking time frame, the average annual

number of STI cases increased 62% more than unfracked counties. Similarly, during that five-year period, the number of cases in heavily-fracked counties increased twice as fast than unfracked counties (Food and Water Watch, 2013). STI transmission is a serious public health issue that can overwhelm health systems and cost communities money by increasing emergency room visits and treating often uninsured patients. Other fracking boomtowns, like those in North Dakota, have experienced similar public health issues, including increased instances of sexual and domestic assault.

It is clear that fracking has implications for communities beyond environmental impact. Issues related to health, safety, and increased local costs can create significant social problems for rural areas where fracking is prevalent. Areas of Texas, where fracking has been occurring at high frequencies, may also be experiencing some of the issues that have occurred in Pennsylvania. It is important that localities and states work to develop a better understanding of impacts through studies like these, in order to mitigate against the problems they can cause. In addition, communities should be looking to severance tax and impact fee programs that shift some of the financial burden for local issues to the private fracking companies helping to cause them.

TEXAS

Texas continues to experience an oil and gas boom from shale drilling. The actual tax revenue from 2012 far exceeded estimates. Texas Oil and Gas Association consultants estimated that Texas earned \$12 billion in 2012, which was an increase from \$9.25 billion in 2011 and \$7.4 billion in 2010 (Galbraith, 2013). Of these taxes paid, approximately \$2.1 billion was paid in severance taxes for oil production, \$1.5 billion for natural gas production in 2012. These severance taxes, or taxes paid on production, are pooled in the state's Rainy Day Fund, which is currently being considered for use in funding infrastructure projects. In late 2013, Proposition 6 was approved, which amended the state constitution to allow some of the Rainy Day Fund to be allocated to a State Water Implementation Fund (SWIF). This fund will be used to implement elements of the state water plan, including infrastructure projects to aid drought issues for the state (ballotpedia.org, 2014). Property taxes paid by the oil and gas industry are directed to local governments. In 2012, about \$3.6 billion were collected in property taxes. Local municipalities in turn have discretion over how those funds are put to use.

Tax revenue from oil and natural gas production in Texas is providing the state with opportunities to reinvest in projects, like water infrastructure, that are likely to produce important benefits for constituents. But in counties most directly affected by shale drilling, tax revenue from oil and gas does not always trickle down. The shale boom towns of the Eagle Ford play in southern Texas still continue to experience extreme poverty. Very little of the funds are allocated to social services and programs for the poor, who are often most directly affected by environmental impacts of hydraulic fracturing.

A report published by the Federal Reserve Bank of Dallas found that in colonias in six border counties in Texas, 42% of families lived below the federal poverty line, with a median household income of \$29,000 (Fernandez and Krauss, 2014). La Salle County, directly in the heart of the Eagle Ford Shale, was found to have approximately 39% of children living in poverty. While local school districts have benefitted from additional funding, communities are also dealing with the most significant health risks associated with fracking activity. “During the peak ozone season in 2012, Eagle Ford operations in La Salle County daily emitted 12.8 tons of nitrogen oxides and 28 tons of volatile organic compounds — pollutants that produce smog and can cause health problems — according to a report prepared by the Alamo Area Council of Governments” (Fernandez and Krauss, 2014).

These types of conditions have led one Texas town located near the Permian Shale in west Texas to seek a ban on fracking. The city of Denton will vote in November 2014 elections on whether or not to place a moratorium on fracking within city limits. If the ban passes it may start a, “precedent-setting legal battle that would help clarify the authority of local governments over oil and gas operations in Texas” (Dropkin, 2014). Local municipalities have little authority over how permitting for drilling is handled, although they can set local ordinances to protect impacts on health and safety. If the ban is passed, it is likely to face legal challenges, but a moratorium precedent on fracking in Texas may open the doors for other cities and counties throughout the state that are concerned with the impact of drilling on their communities. Future efforts to limit the extraction and production of natural gas could become a barrier to future growth of NGVs and natural gas infrastructure.

NATIONAL POLICY

The policy implications of fracking and the desire to be energy independent have recently taken national center stage. On March 15, 2013, President Obama released his *Blueprint for a Clean and Secure Energy Future*. It outlines his reasoning and plan for the U.S. The blueprint cites falling oil imports, and lowered greenhouse gas emissions, but rising gas prices as evidence that we are “still too reliant on oil” (The White House, 2013). The Administration is calling on Congress to establish an Energy Security Trust. “The Trust is designed to invest in breakthrough research that will make the technologies of the future cheaper and better technologies that will protect American families from spikes in gas prices and allow us to run our cars and trucks on electricity or homegrown fuels” (The White House, 2013). The Trust relies on a coalition of bipartisan stakeholders that looks to promote cost-effective transportation alternatives, and would be funded with \$2 billion over the next ten years, from royalties from oil and gas development of the Outer Continental Shelf energy reserves, and is touted as an “all of the above” approach to energy sources. Included in the plan are specific proposals dealing with natural gas and NGVs.

The plan embraces an all of the above approach with the following:

- Sets a goal to cut net oil imports in half by the end of the decade.
- Commits to partnering with the private sector to adopt natural gas and other alternative fuels in the Nation’s trucking fleet.

- Establishes a new goal to double American energy productivity by 2030.
- Challenges states to cut energy waste and support energy efficiency and modernize the grid.
- Commits to build on the success of existing partnerships with the public and private sector to use energy wisely.
- Calls for sustained investments in technologies that promote maximum productivity of energy use and reduce waste.
- Leads efforts through the Clean Energy Ministerial and other forums to promote energy efficiency and the development and deployment of clean energy.
- Works through the G20 and other forums toward the global phase out of inefficient fossil fuel subsidies.
- Promotes safe and responsible oil and natural gas development.
- Updates our international capabilities to strengthen energy security
- Supports American nuclear exports (The White House, 2013).

Although the Trust specifically touts partnering with the private sector to adopt natural gas in the nations trucking fleet, one must view the Trust comprehensively. The greatest adoption factor, the natural gas price differential, will continue to rely on favorable natural gas development policy and the acknowledgement that natural gas and NGVs are a key factor in energy security and reduction in greenhouse gases.

CONCLUSION

Natural gas has been touted as the fuel of the future. Globally, the demand for natural gas has tripled over the past thirty years and is forecasted to grow another fifty percent in the next twenty years (Yergin, 2012). As populations increase and developing nations escalate their demand for fuel, the global market will become increasingly more competitive. This increased competition may lead the U.S. to become susceptible to market fluctuations leading to a less secure future.

That being said, the U.S. is at a crossroads. The opportunities to have an updated comprehensive energy policy, that embraces natural gas, will allow the U.S. to continue to compete globally. Hydraulic-fracturing technologies and the ability to access natural gas offers the U.S. the ability to harness a domestically produced fuel to power our homes, industrial needs, and our vehicles. It not only burns cleaner, improving air quality, but has given the U.S. the opportunity to strengthen our national security with the possibility of becoming increasingly energy self-sufficient. Decisions and consensus is needed to produce an energy policy that will alleviate environmental concerns while promoting a secure and stable future.

With increasing global fuel demand, the U.S. is in the process of diversifying its energy sources which provides the benefit of not being subject to the volatility of the international fossil fuels market. The increased production and adoption of Natural Gas Vehicles (NGVs), coupled with expansion of existing infrastructure, have the ability to immediately nudge the U.S. further in that direction. NGVs have the capability to bridge the gap between traditional fuel vehicles and emerging technologies which can reduce our dependence on imported energy fuels. On the federal level, there are incentives and an increasing desire to develop a comprehensive energy policy. States, in particular, have incentivized the development and use of natural gas, and refueling stations to level the playing field against traditional fossil fuels vehicles.

As natural gas begins to make inroads as a viable transportation fuel, the nation will need a proactive policy to address upcoming challenges. The technology is available, and price disparities lend themselves to the adoption of NGVs, and the infrastructure is following close behind. To aid in the adoption and expansion of NGVs, we propose the following in order to propose a national energy policy.

Assess the lessons learned from energy-rich states and adopt them as appropriate. Texas, Pennsylvania, and North Dakota are experiencing huge expansions in natural gas drilling, and, in turn, are facing the environmental and community challenges associated with hydraulic fracturing. Texas has enacted legislation specific to its large communities to improve air quality with the Texas Clean Transportation Triangle. Second, produce a non-partisan environmental study. Every state appears to be addressing hydraulic fracturing and environmental issues in their own ways. While local control is encouraged, there has yet to be a report released that is comprehensive and provides consensus. Without comprehensive reports, states and localities are forced to make decisions regarding fracking that are often based on biased reports or are susceptible to industry or environmental group pressure. This impedes comprehensive decisions, which leaves businesses struggling to operate, while expending a lot of financial resources in the public affairs realm. Third, the abundance of natural gas and NGVs deserve federal and state research and development that can produce reports and policy suggestions so the U.S. can

capitalize on the natural gas revolution. Similarly, R&D efforts stand to make enormous inroads into an expanding NGV market, producing cheaper fuel-efficient vehicles.

These recommendations are by no means all inclusive, but would point the industry, environment, and the U.S. public in the right direction. The U.S. is now grappling with the fact that energy independence could be a reality. We have gone from fearing an end of fossil fuels to producing an abundant, cheap, clean burning fuel. The U.S. transportation system should embrace and expand its use of NGVs. NGVs provide the U.S. with the ability to utilize the abundant natural gas, improve air quality, all while strengthening our national security.

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